

Assessing the Potential of Creating a Stream Mitigation Bank on the Tar River

by

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May 2015

Masters Project submitted in partial fulfillment of the  
requirements for the Master of Environmental Management degree in

the Nicholas School of the Environment of

Duke University

2015

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## **Executive Summary**

The prospectus of the Tar River Land Conservancy (TRLC) in mitigation banking arises from discussion with other organizations interested in a partnership with TRLC to generate stream mitigation credits from conservation easements managed by TRLC. As a result of those discussions, TRLC seeks to identify the possibilities of creating their own mitigation bank. This report serves as a tool to assist TRLC in their decision-making process to determine the feasibility of creating a mitigation bank that is both economically sustainable and affirms the mission of the land trust.

The first section of this reports provides an overview to the regulations surrounding mitigation banking from Section 404 of the Clean Water Act. A review on mitigation banking outlines the role the bank plays as an outlet for mitigating environmental impacts to streams and wetlands to manage for zero net loss of ecological habitat. The section also outlines the study area in which the report focuses on and characteristics of the Tar River basin.

The second section provides an overview of the three main objectives outlined in the study. These objectives focus on identifying potential sites for starting a bank, challenges to mitigation banking as a land trust, and the business aspects related to mitigation banking.

The third section details the methodology of the study and is broken down into three parts in accordance to the three outlined objectives. The first objective applies GIS modeling to identify streams of great potential and is subdivided into 2 phases. Phase I provides an initial sub-watershed characterization for the 27 identified sub-watersheds in the upper Tar River basin. Characterization of these sub-watersheds incorporate 6 factors which are then weighted to determine overall priority of areas to focus on for further analysis. Phase II, a detailed

assessment of prioritized sub-watersheds, applies water quality and sedimentation loads to isolate stream projects for the mitigation bank and to rank sites by greatest mitigation activity potential.

Objective 2 describes a national literature review of land trusts already engaged in mitigation banking. Primary sources are presented defining the initial search for land trust mitigation banks and those challenges faced by land trusts as provided in the relevant literature.

Objective 3 examines the costs related to mitigation banking, available funding sources, and market values at which stream credits are currently sold. This section also identifies current mitigation banks and Local Watershed Plans (LWP) within the study area.

The fourth section discusses the results identified from the analysis. Elements of sub-watershed and stream prioritization, first covered in Objective 1 and proceeds to summarize challenges faced by land trusts and provides recommendations for meeting identified challenges in Objective 2. Objective 3 provides information about the cost range of mitigation banks; and, to determine total economic returns after credits are sold. In addition, funding sources, and identification of current mitigation banks and LWPs are reviewed. Based on cost and market price values coupled with our GIS analyses, specific stream projects were identified and prioritized.

The fifth section is a discussion of current population trends in North Carolina that may influence mitigation activities in the study area. This import consideration provides recommendations as to how TRLC can provide direction to mitigation banking to overcome the limitations faced as a land trust. The latter part of the section discusses 303d Category 5 impaired streams and proposes sites for consideration to improve stream quality.

The sixth and final section highlights overall recommendations based our analyses. Important findings are: identification of those sites with greatest restorative potential and enabling a land trust in the mitigation banking process.

Certain complexities in mitigation banking present challenges to TRLC as a land trust. While there is potential for involvement in the mitigation process, considerations must receive thorough attention to ensure project success. Professional assistance from consulting firms and organizations increases both the level of expertise required for the business enterprise and alleviates workload stress on the land trust. Aside from the sites identified, other potential sites to consider include streams running on properties not currently owned by TRLC with similar characteristics to sites identified in the report.

## **Introduction**

This assessment is a Group Master's Project serving the Tar River Land Conservancy (TRLIC), a private land trust in North Carolina, whose mission is to "preserve the natural and cultural resources of the Tar River basin and surrounding areas (Tar 2014). Private consulting firms and other organizations have approached TRLIC concerning a partnership to secure mitigation credits through conservation easements. As a result of those talks, TRLIC is interested in the feasibility of creating a sustainable business plan in stream mitigation banking with the focus being conservation easements, while also affirming the mission of the land trust. Specifically, the essential goal of preserving the natural and cultural resources of the Tar River basin by working with local private landowners and public agencies to protect drinking water, wildlife habitat, farms, forests, and recreational areas.

Discharge of dredged or fill materials into U.S. navigable waters and wetlands is regulated by Section 404 of the Clean Water Act (Federal 2002). Activities regulated under this program include fill for development, dam and levee construction, infrastructure development, and mining projects (Compensatory 2015). To receive approval for discharge, entities must apply for a permit issued by the Army Corps of Engineers (USACE) only after proving that steps were taken to avoid environmental and ecological impacts, potential impacts were minimized, and compensation is provided for impacts created (Compensatory 2015). Three options exist for compensating environmental and ecological harm: permittee-responsible mitigation, mitigation banking, or in-lieu fee. Of the three above approaches, mitigation banking is the popular option that has grown economically since 1991 (Robertson 2006).

Mitigation banking allows a bank sponsor to identify a degraded wetland or stream site, utilizes funds to create, restore, enhance, or preserve the ecological and hydrological features of

the site, and generate credits that can then be sold to clients looking to offset environmental impacts. This would be the role of TRLC. Since August 2013, over 1,800 banks have been recorded in the Regulatory In-lieu fee and Bank Information Tracking System (RIBITS) managed by USACE (Mitigation 2014).

In parts of North Carolina, projected population growth increase the potential for mitigation banks. A study by John Chesser (2014) found that Raleigh, NC is expected to be the second fastest growing city in the U.S. in terms of population 2010 to 2030 after Charlotte, increasing by 70%; additionally Durham is expected to grow by 33%. Important to the city's growth is the impact felt on surrounding regions of the Research Triangle. Nearby river basins such as the Tar River basin face potential development from road construction/maintenance, housing development, and other infrastructure. Furthermore, a study by Terando et al. (2014) predict an urban sprawl in the southeastern U.S. in the next 50 years, with an urban corridor to stretch from Raleigh to Atlanta to create another megalopolis and expanding the urban corridor along the entire coast of the eastern U.S. Where streams and wetlands intersect development, mitigation banking serves as an available option to offset unavoidable environmental losses.

### *Study Area*

The assessment of the study focuses on the Upper Tar River basin stretching across Person, Granville, Vance, and Franklin Counties in North Carolina with an area of 792 sq. miles (2051km<sup>2</sup>). High levels of nutrients in the Tar River have induced large algal blooms and fish kills (Tar-Pamlico 2015). As a result, the Tar River basin, along with the Pamlico River basin, are listed as Nutrient Sensitive Waters and strictly regulated under state law (N.C. 2000). The Tar River also hosts federally and state threatened/endangered aquatic species, such as the spiny mussel (*Elliptio steinstansana*), dwarf wedgemussel (*Alasmidonta heterodon*), and triangle

floater (*Alasmidonta undulate*); additionally indigenous species like the Roanoke bass (*Ambloplites cavifrons*) are under concern for potential danger of extinction (Endangered 2013).

## Objective

Our project aims to assist TRLC to determine the potential of creating a mitigation bank. The overall objective of the project comprises three specific objectives: 1) identify and rank sites suitable for a mitigation bank within the Tar River basin; 2) conduct a national literature research on land trusts across the U.S. that have engaged in mitigation banking enterprises to determine liabilities/pitfalls and to develop recommendations to overcome the challenges; and 3) assess the feasibility of creating a business plan and identify those elemental factors for sustaining a business plan that is consistent with the mission of TRLC, specifically by improving in-stream and riparian buffer areas within properties owned by TRLC through conservation easements.

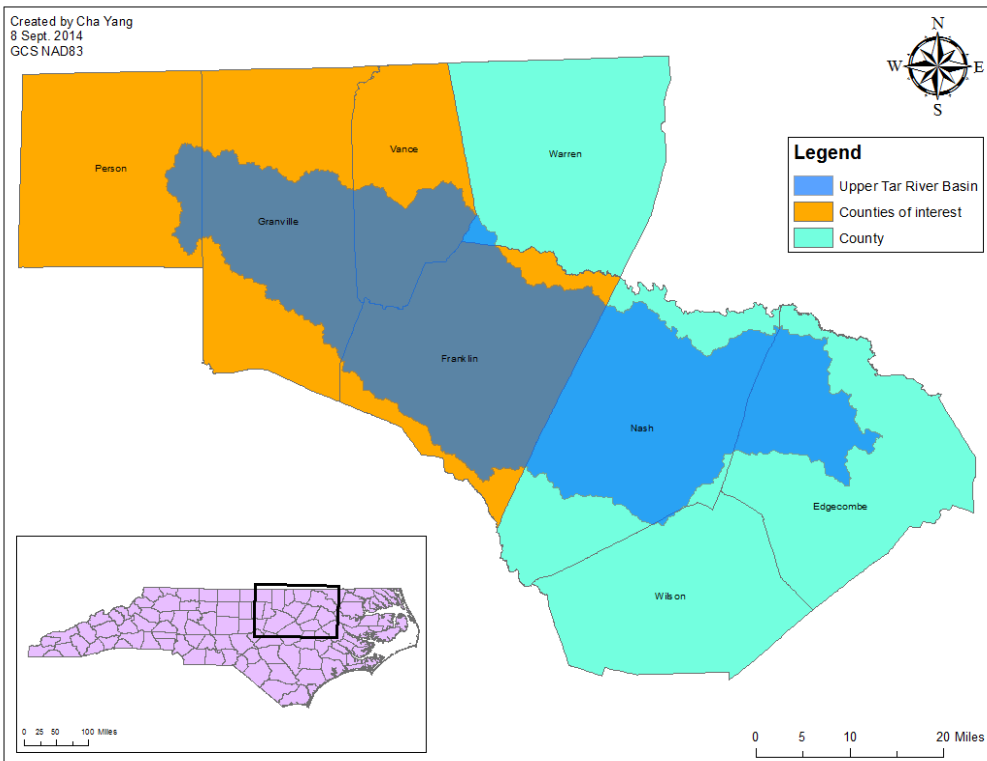


Figure 1. Tar River basin site study area and those specific North Carolina counties involved.

## **Methodology**

### ***Objective 1 Watershed Characterization***

Objective 1 was divided into two phases, Phase I: Preliminary Watershed Characterization and Phase II: Detailed Site Assessment. Phase I, an initial watershed characterization, assembled and analyzed existing information, and structured them as a metric for further analysis. For a detailed assessment, the Tar River basin was broken down in sub-watersheds at the hydrologic unit code (HUC) 12 level, dividing the basin into 27 sub-watersheds. Prioritization of sub-watersheds was conducted based on six potential stressors or watershed characteristics. Phase II is a more detailed assessment of field conditions based on Phase I results focused on sub-watersheds that were scored as medium-high or high priority. Both phases applied geospatial information system (GIS) and other spatial analysis programs to achieve results. For GIS, work was completed using ArcMap 10.2.

#### ***Phase I: Preliminary Watershed Characterization***

In the preliminary characterization, aquatic species, soil type, stormwater, agriculture, forestry, and riparian buffer were combined to establish a general characterization of each sub-watershed within the Upper Tar River basin. Characterization for these 27 sub-watersheds was developed in ArcMap (Figure 2).

To determine the total value (species, agriculture, and forestry) or average value (soil, stormwater, and riparian buffer) per sub-watershed, Zonal Statistics tool was applied to calculate the values of interest and provide a summary table. For easy interpretation, the sub-watersheds were re-assigned new categorization values (Appendix).



Figure 2. Tar River sub-watersheds.

### Aquatic Species of Concern

We focused on those aquatic species listed as federal or state endangered or species-of-concern, such as certain freshwater mussels (Endangered 2013). Assumptions were made that sub-watersheds with greater presence of upstream mussel occurrences were more likely to see recruitment in terms of stream restoration. Data for aquatic species were provided by the TRLC with permission of use from the North Carolina Natural Heritage Program, spanning from 1963-2013. To reduce data error and provide a more accurate representation of current distribution, the analysis focused on data ranging from 2005-2013. The total number of mussel occurrences for each sub-watershed was summed by Join tool in ArcMap (Join data based on spatial location) and exported as a table.

### Location of Highly Erodible Soils

Highly erodible soils can increase sediments loading into streams and potentially impair and reduce the biodiversity of the watershed (W. K. Dickson 2012). The erosivity index, K factor, was applied to assess soil erodibility. K factor values for each soil type came from the NRCS SSURGO database (Geospatial 2014). The values were averaged to ascertain mean K factor value per sub-watershed (Figure 3).

### Stormwater

Stormwater runoff can cause significant pollution to streams and waterbodies. As a non-point source, effective management proves difficult to implement (W. K. Dickson 2012). Impacts of stormwater runoff are typically proportional to the amount of impervious surface area present in the watershed (W. K. Dickson 2012). Therefore, percent impervious area was substituted for stormwater in the analysis. Data came from the Multi-Resolution Land

Characteristics Consortium (MRLC) (National 2014). Figure 4 shows the mean percent impervious cover within each sub-watershed.

Table 1. Mussel site analysis

<b>Sub-watershed</b>	<b>Number of species</b>
1	4
2	8
3	46
4	2
5	33
6	2
7	5
8	0
9	4
10	50
11	1
12	0
13	0
14	0
15	0
16	0
17	0
18	1
19	5
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0

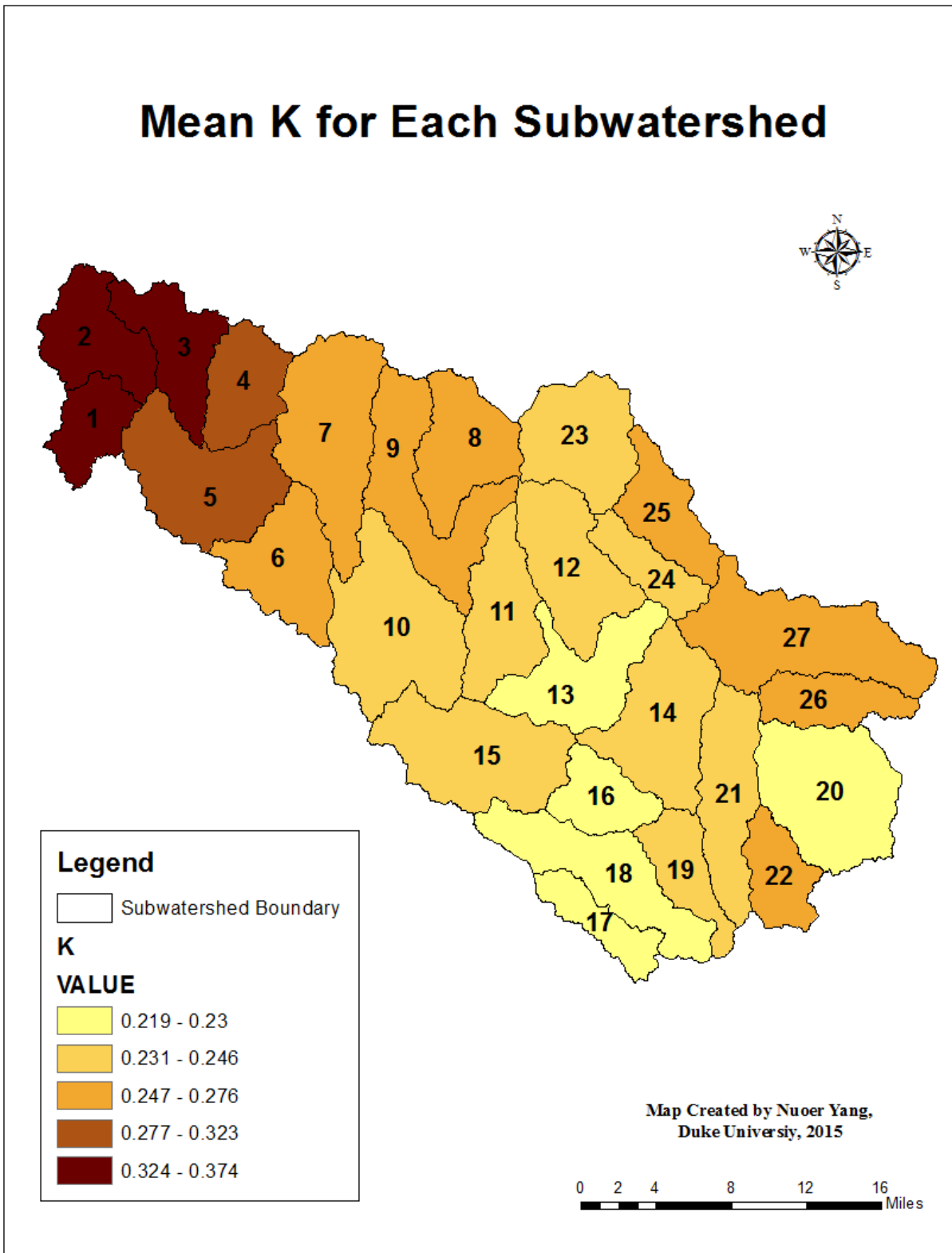


Figure 3. Mean soil K factor for each sub-watershed.

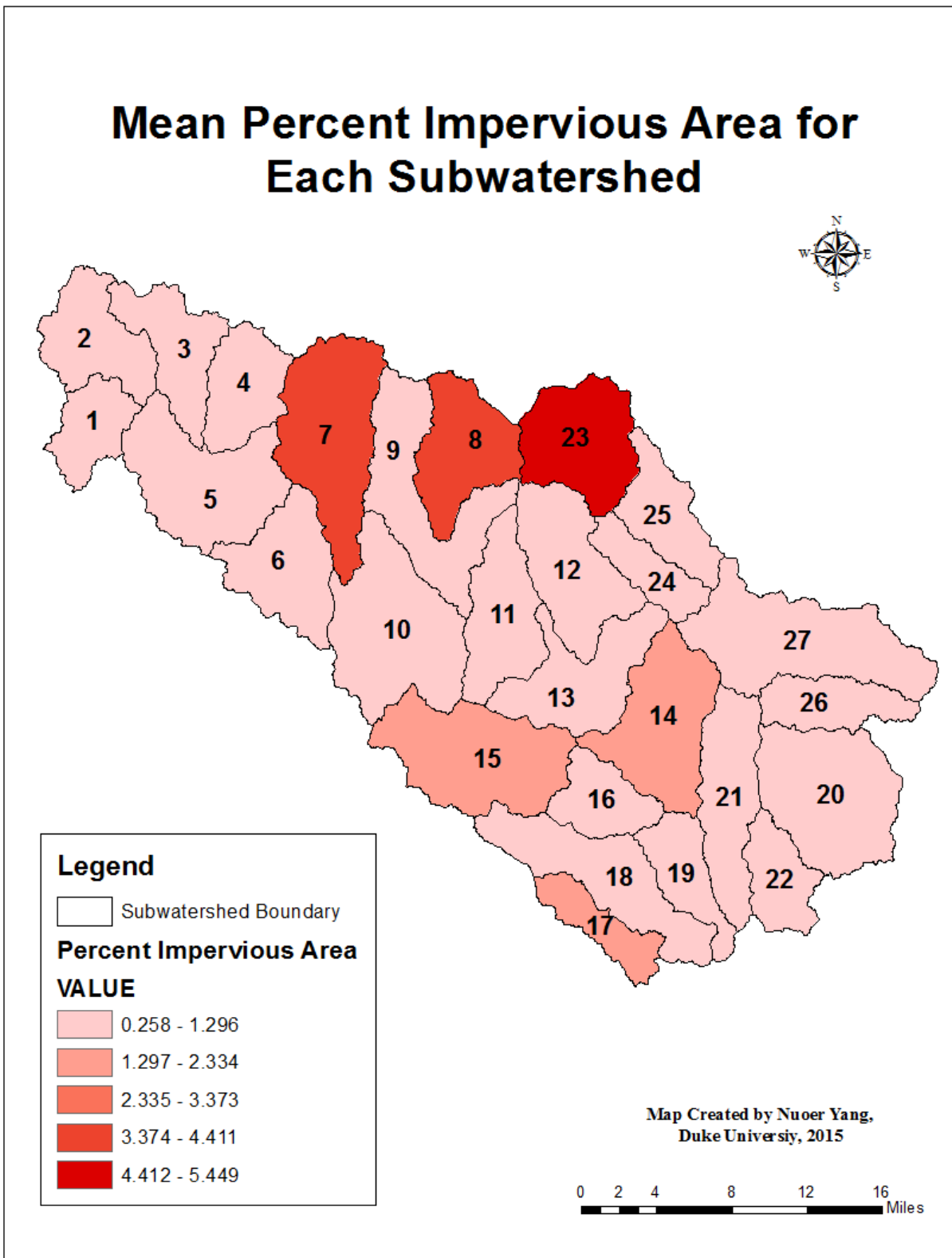


Figure 4. Percent impervious surface area.

## Agriculture

Application of agricultural fertilizers or pesticides results in the degradation of water quality via stormwater runoff or the interaction between streams and adjacent lands. Apart from nutrient input, agricultural activity also increases sediment loading to nearby streams (W. K. Dickson 2012). Agricultural land cover was extracted from the 2011 National Land Cover Dataset (NLCD) focusing on cultivated crops (National 2014). Figure 5 presents the total agricultural area for each sub-watershed.

## Forestry

Forestry, contrary to agriculture, may offset the degradation that agriculture poses to streams. Vegetation can strengthen the stability of the soils, reducing vulnerability from erosion. In addition, forestry is less impervious, which could attenuate the effect of stormwater runoff. Similar to the methodology of agriculture mentioned above, the total area for each sub-watershed was calculated, combining deciduous, evergreen, and mixed forest from the NLCD (Figure 6). Spatial data on forestry activities within the river basin were not identified. The primary concern with logging is the frequency of activities within the area, which was assumed to be zero with absent data. On the contrary, logging and clear cutting along riparian zones is not a concern as logging is prohibited in riparian zones of the Tar River basin under rule .0259 (N.C. 2000).

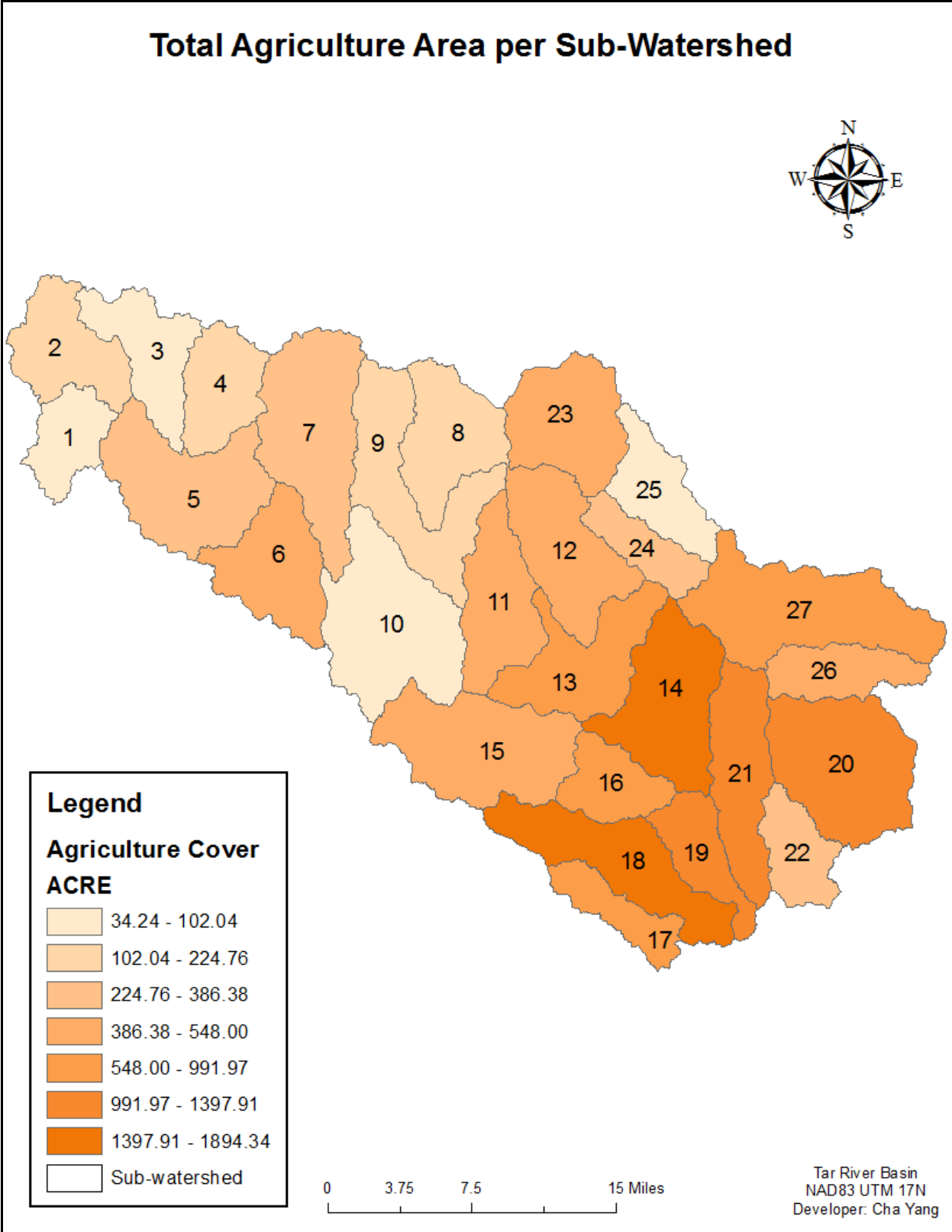


Figure 5. Total agricultural area per sub-watershed.

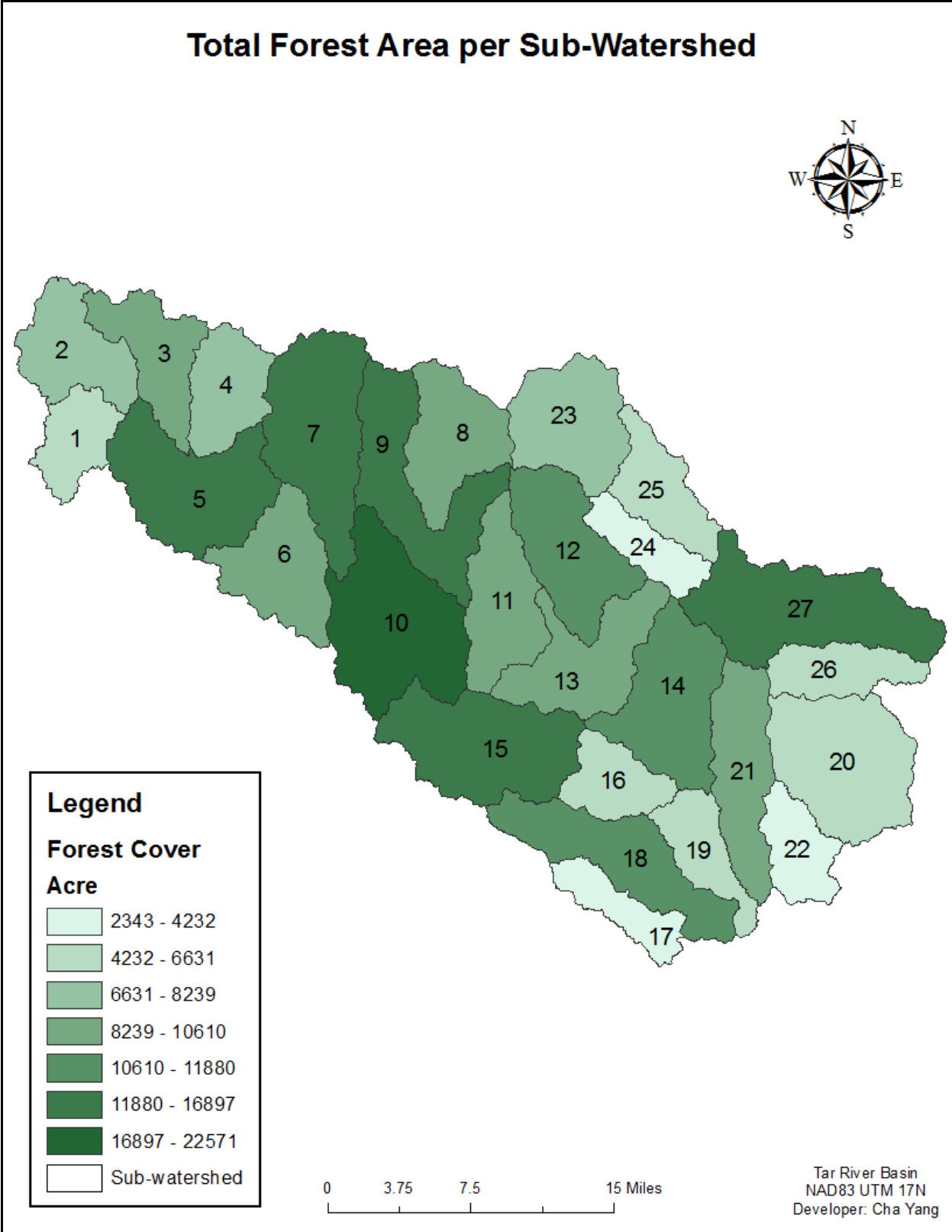


Figure 6. Total forest cover per sub-watershed

## Riparian Buffer

Riparian buffers are defined as “a vegetated area bordering a body of water, such as a stream, lake, or pond” (Riparian 2015). These buffers protect streams by providing shade and mitigating impacts of adjacent land use. Buffer zones serve to intercept sediment, nutrients, chemicals, and other materials in surface runoff, reduce nutrient and pollutant loading in streams, provide habitat and wildlife corridors in agricultural areas, and reduce erosion by trapping particulate matter (NRCS 2003). These buffers serve as a more comprehensive index to predict stream conditions, which integrates the impacts of anthropogenic factors, agriculture in particular, with the offsets of forestry connected to streams. A flow path method was applied in ArcMap to calculate the distance between source of pollution and stream along the path of steepest descent. Digital Elevation Model (DEM) and hydrology data were downloaded from NRCS Geospatial Gateway (Geospatial 2014). A model was built to first isolate all source cells (cultivated crops) and their hydrologic path to stream cells into a new raster layer, which created a source path indicating the flow cost distance to the stream. Based on the distance values, average buffer capacity of each sub-watershed was obtained. From Figure 7, low values represent low buffering quality and indicate lower stream quality, suggesting potential restoration activity geared toward generating credits.

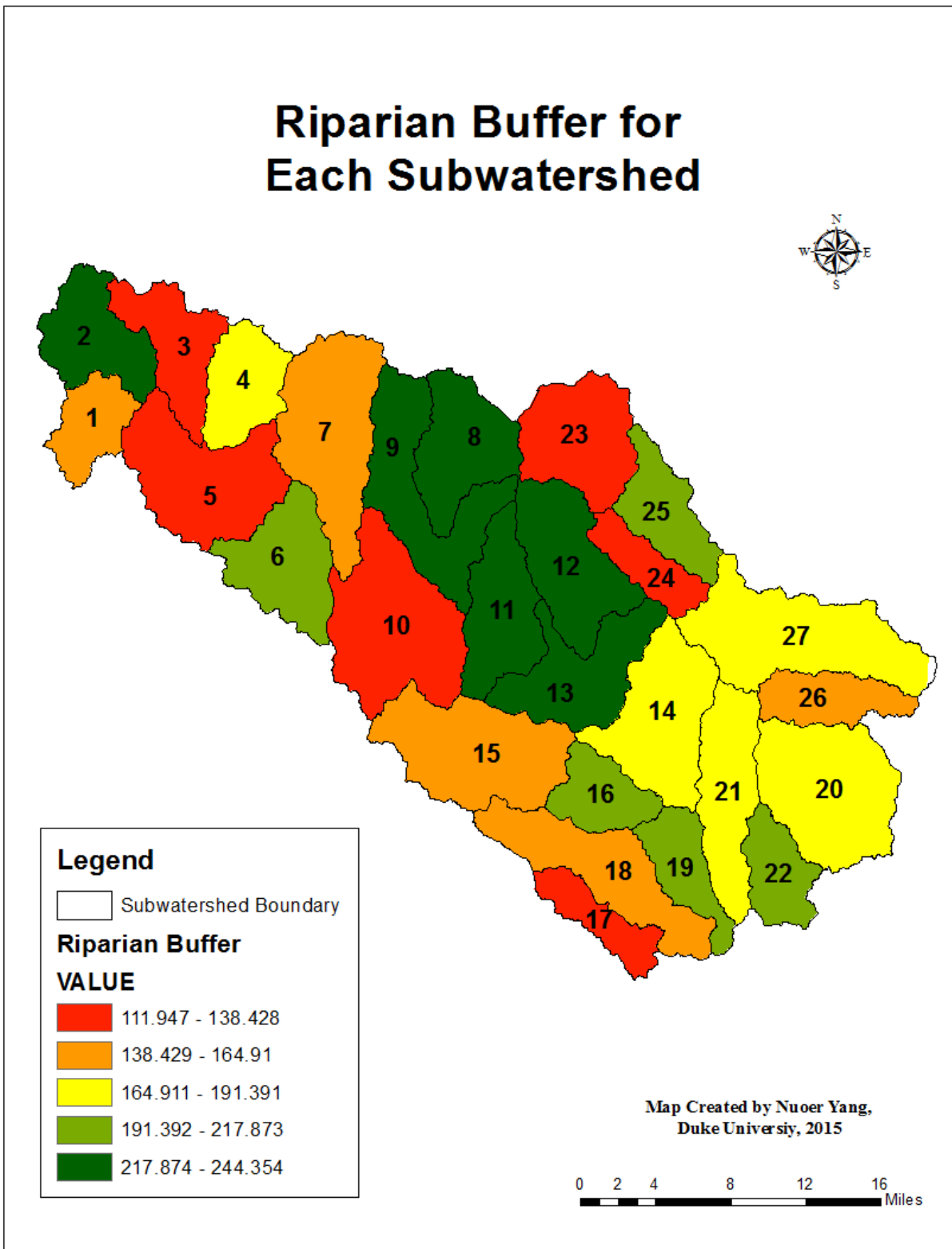


Figure 7. Riparian buffer capacity per sub-watershed.

The values of each parameter were rescaled and reclassified into 5 classes. Each class was assigned a new value based on project priority as presented in Table 2. Desirable areas for the analysis had higher values and thus higher priority. Each parameter was weighed against each other to evaluate overall significance level (Table 3). Because riparian buffer, to some degree, integrates aspects of both forestry and agriculture and strongly influences stream health, it received greatest weight among the six parameters.

Table 2. Value assigned to the five priorities.

Value	Priority
1	Low
2	Medium-low
3	Medium
4	Medium-high
5	High

Table 3. Weight factor assigned to each parameter.

Factor	Weight (%)
Endangered Species	17
Soils	17
Stormwater	10
Agriculture	15
Forestry	15
Riparian Buffers	26

### *Phase II: Detailed Watershed Assessment*

Phase II evaluated the physical conditions of key watershed functions based on modelled results in Phase I. Water quality, sedimentation estimation, and stream reach analysis applied the PLOAD and GIS-based RUSLE models, and GIS, respectively.

#### PLOAD Model

Water quality for the PLOAD model was developed using BASINS 4.1, an environmental analysis program developed by the U.S. Environmental Protection Agency (EPA)

to estimate annual loading of nonpoint sources for watersheds. The model followed the Simple Event Mean Concentration (EMC) method, with information input including pollutants (nitrogen and phosphorous), annual precipitation and storm runoff ratio, and land cover. Data for the EMC table were taken from the PLOAD User’s manual for North Carolina (PLOAD 2001; CH2M 2000). Annual precipitation data came from the National Ocean and Atmospheric Administration (NOAA) for the years 2011-2013 and averaged (Advanced 2014). The storm runoff ratio was set to the default value of 0.90. Land cover data came from the NRCS (Geospatial 2014). The output generated a table estimating annual non-point source pollution loading rate for each defined sub-watershed.

RUSLE Model

The Revised Universal Soil Loss Equation (RUSLE) model is an updated method to the USLE approach, which estimates the annual sedimentation load for a particular area (EPA 2014; W. K. Dickson 2012). The model formula incorporates five variables (Table 4). Based on the main principal from the RUSLE model, a GIS-based RUSLE approach was developed to estimate the amount of soil transported from the landscape on an annual basis. Estimation was based on the equation,  $A = R * K * LS * C * P$ .

Table 4. Factors for RUSLE.

<b>Factors</b>	<b>Description</b>
<b>R</b>	Rainfall erosivity factor
<b>K</b>	Soil erodibility factor
<b>LS</b>	Slope length and steepness factor
<b>C</b>	Cover and management factor
<b>P</b>	Support practice factor
<b>A</b>	Annual soil loss from sheet and rill erosion (tons/acre)

R factor represents the ability to drive sheet and rill erosion, which depends on the amount, intensity and distribution of precipitation (Amsalu and Mengaw 2014). Soil is most

susceptible to erosion when the greatest precipitation occurs. Data of annual precipitation were downloaded from NOAA National Climate Data Center (Advanced 2014). According to Cooper (2011), the relationship between R and precipitation in the Eastern United States is as follows:

$$R=1.24P^{1.36}$$

Where, R = Rainfall erosivity; and P = mean annual rainfall (mm/yr).

The average precipitation values were calculated for each metrological station based on the available temporal scale. The R factor was computed using the above equation and then applied in inverse distance weighted (IDW) tool in ArcMap to interpolate a dataset covering the Upper Tar River basin from rain gauges by an (IDW) technique.

K factor measures mean annual rainfall soil loss per unit of R for a standard condition of bare soil. This soil erodibility depends on soil structural stability and the soil ability to absorb water, which in turn is determined by soil characteristics (Amsalu and Mengaw 2014). Data came from soil K factor derived from Phase I.

Slope length and slope steepness factors are commonly combined in a single index as LS, and referred to as the topographic factor (Amsalu and Mengaw 2014). LS was computed based on the following equation (EPA 2014):

$$LS = (m+1)*[(A/a_0)]^{m*}[\sin b/b_0]^n$$

Table 5. Description for LS equation.

<b>Factors</b>	<b>Description</b>
m	0.6
n	1.3
A	upslope contributing area (m <sup>2</sup> ) per unit width (m)
a <sub>0</sub>	22.13, the length of the standard USLE plot
b	slope
b <sub>0</sub>	0.0896

C factor expresses the effect of cropping and management practices on the soil erosion rate (Farhan et al. 2013). In RUSLE, C factor is computed based on the equation:

$$C = PLU * CC * SC * SR,$$

where PLU is the prior land use sub-factor; CC is the canopy sub-factor; SC is the surface cover sub-factor; and SR is the surface roughness sub-factor. Determining each sub-factor was relatively difficult in terms of available information. The normalized difference vegetation index (NDVI) is the most common vegetation index to quantify vegetation biomass and/or plant vigor in a remote sensing image for a certain region (Zhang et al. 2011). Many researchers built the relation between NDVI and C factor based on the predicted mathematical regression (Zhang et al. 2011). Spatial images for analysis came from Landsat 5 TM (CDR) and downloaded from USGS EarthExplorer (Date: April 29, May 15 and July 3 in 2010); NDVI for each image was computed in ENVI and then an average NDVI in the study area was calculated. Since C factor values range from 0 for well-protected soil to 1 for bare soil, 1 and 0 were set to C factor values for bare soil and forest land, respectively. Random points were created in the ArcMap, and NDVI and land type values were extracted from the average NDVI dataset and NLCD. However, no satisfied regression was found due a low  $R^2$  value. Therefore, C factor was computed based on the equation below (Suriyaprasit and Shrestha 2008):

$$C = 0.227 \exp^{-7.337 \text{ NDVI}}$$

The majority of the basin was associated with a relatively low C factor.

P factor in the RUSLE model represents the effect of conservation practices that reduce soil erosion by reducing the amount and rate of water runoff (Farhan et al. 2013). Different types of agricultural management practices (e.g., strip cropping, contouring and terracing) correspond

to different P factors (Farhan et al. 2013). P factor was derived based on the each land use/cover type and slope.

Table 6. Support Practice factor (P).

<b>Land Use Type</b>	<b>Slope (%)</b>	<b>P Factor</b>
Agriculture	0 - 5	0.1
	5 - 10	0.12
	10 - 20	0.14
	20 - 30	0.19
	30 - 50	0.25
	50 - 100	0.33
Other land	-	100

The data layers (maps) extracted for each factor of the RUSLE model were integrated within the Raster Calculator tool of ArcMap in order to quantify the annual soil erosion.

#### Stream Reach Analysis

The stream reach analysis applied guidelines for restoration and enhancement utilized by W.K. Dickson (2004) in their report for the Fishing Creek Local Watershed Plan. These parameters include:

- Minimum length of 1,500 linear feet.
- Stream order value of 3 or less following the Strahler stream order.
- Intersection through 3 or fewer land owners.
- Presence of unforested/wetland riparian buffer.

The stream site selection ultimately narrowed down to streams meeting the above criteria and running through land protected by TRLC (i.e. land ownership or conservation easements).

Assessment of the methodology applied GIS to model and select streams of interest. First to third order streams were extracted using 30m DEM downloaded from NRCS (Geospatial 2014).

While stream spatial data already exists within the National Hydrography Dataset (NHD), the data does not provide information on stream order. Stream features were further refined by

selecting sites at least 1,500 linear feet in length. Input of land parcels narrowed sites to those intersecting three or fewer land owners. 2014 land parcels were provided by TRLC for the four counties of the study area.

Using the selected streams, a 100-ft buffer was created and overlaid with the NLCD to identify non-forested and non-wetland riparian zones surrounding the streams. As a nutrient sensitive waterway, the Tar River and its tributaries require at least a 50-ft buffer from any nearby activity (N.C. 2000). Furthermore, a study by Clinton (2011) found that buffer strips with a width of 10 m (33-ft) prevented large water quality impairments from timber harvesting. Applying a 100-ft buffer aims to target the nutrient-loading challenge and improve water quality. Streams containing these buffer regions were kept and further processed by eliminating those outside TRLC-protected lands. The preliminary stages of this assessment are focused on stream sites intersecting conservation easements under TRLC but can later identify sites outside of TRLC. Because the results are based on DEM data, the information provides no information about stream names. Overlaying the results to the NHD stream data identified streams of interest running through targeted lands.

Based on the selected stream segments above, stream prioritization was conducted to determine which streams have the highest potential for creating a stream mitigation bank. High scores are associated with high prioritization, which ideally would be suitable sites for a mitigation bank to generate the most credits. In our stream score assessment, nine criteria were employed (W. K. Dickson 2012): 1) stream length and landowner limitation (streams that are too short are not cost-effective for a mitigation bank. Additionally, more landowners involved increases the complexity and difficulty in implementing a mitigation project); 2) stream order (if the stream order is greater than 3, we considered it as a relatively unfeasible site); 3)

channelization(a channelized stream would be given higher score, as it is less natural with human disturbance); 4) stream buffer condition (streams adjacent to agriculture or pasture would be assigned higher score, compared to those surrounded by forest); 5) mussels recruitment(reaches with larger probability to attract mussels would be assigned higher stream scores); 6) channel stability (less stable stream channels are more susceptible to soil sedimentation loads, and therefore higher priorities are given to those streams with less stability);7) stakeholder identification; 8) sub-watershed priority (priorities result from our primary watershed characterization; and 9) TN/TP limitation (the nutrient management strategy for the Tar River basin limits new development from releasing nitrogen and phosphorous at an annual loading rate of 4 lbs/acre and 0.4 lbs/acre respectively (N.C. 2001)).

### ***Objective 2 Pitfalls and Liabilities***

A literature search using Google Scholar and other databases collected information about trends in mitigation banking, challenges, and analyses of its effectiveness relating to land trusts across the U.S. An initial search on the Regulatory In-lieu fee and Bank Information Tracking System (RIBITS) database and Land Trust Alliance website provided information about land trusts that have established mitigation banks. Challenges to the literature research arose due to lack of information detailing the success rates of land trusts. Much of the information may exist in proprietary and would require talking to individual banks. Furthermore, no peer-reviewed articles have focused on land trust mitigation banking. One land trust, The Environmental Trust (TET), came up during the search and served as a main proxy for researching challenges and applicable tools. Challenges included project design and management, financial assurances, adequate expertise, and prevention of site degradation. The data collected informed the study by describing obstacles faced not only by TET but also by other land trust mitigation banks and

private banks. More readily available information from private banks provided general, applicable information when considering getting into the business. The information also assisted with outlining recommendations on the factors mentioned above.

### ***Objective 3 Business Plan***

Four components were assessed with developing the business plan: project costs, funding sources, market return, and presence of other banks. Because majority of the information appear to exist in proprietary, accessible information was limited. A search conducted on the NCEEP website identified reports discussing project costs. The EEP publishes an annual report of its progress, part of which details funding allocation. The report breaks down cost to multiple contract services, along with expenses per program sector (e.g. NCDOT Stream and Wetland Program, Riparian Buffer Program, Nutrient Offset Program, etc.). Using the values identified, project costs for each of the stream sites isolated from Objective 1 were estimated assuming only restoration activities with a 1:1 compensatory mitigation ratio (Stream 2003) and complete restoration of streams within conservation easements.

Researching for funding sources included federal, state, and private grants and programs designed to promoting land trust activities or environmental stewardship, particularly in water resources. Targeted grants and program focused on stream and riparian buffer restoration, water quality, land stewardship, land trust land acquisition and restoration, and fish/aquatic wildlife conservation. The search does not provide a comprehensive list but presents a starting point to consider when creating the bank.

Similar to project costs, finding market prices of stream credits presented challenges. Purchasing stream credits are typically negotiated between the bank and client seeking to purchase credits but may range anywhere from \$15-\$700/linear foot (Market 2014). Due to the

long range, emphasis was placed on the North Carolina market. The EEP provides transparency of its price range for stream credits, which was used to compare to other private banks where information was accessible. The price per stream credit was also applied to estimate the return from selling all stream credits per site. This was compared to project costs to determine potential revenue from engaging in mitigation banking.

Identifying present and past banks provides an understanding to where current credits are needed and the potential competition that may exist as a result of creating the bank. The RIBITS database and EEP listed banks engaged in mitigation or in-lieu fee activity, ranging from pending applications to sold out credits. Valuable information gathered from these databases includes active banks and their locations. Another related importance to bank presence are local watershed plans (LWP) developed by EEP. LWPs identify specific regions with crucial watershed issues of community concern. From these targeted areas, EEP coordinates efforts to restore site as mitigation projects (Watershed 2015). LWPs were listed on the EEP website, which also highlights Targeted Local Watersheds, areas of concern that have not yet received management planning.

## **Results**

### ***Objective 1 Watershed Characterization***

#### *Phase I: Preliminary Watershed Characterization*

Figures 8-13 show results of each parameter for Phase I. From the aquatic species of concern analysis sub-watersheds 3, 5 and 10, were classified as medium-high to high priority, which occur in the northwestern part of the river basin. Similarly, higher priority for erodible soil was located in the upper region with greatest priority for sub-watersheds 1, 2 and 3. In the agricultural analysis, the lower part of the basin received highest priority, in particular sub-watersheds 14, 18 and 19. Unlike agriculture, forestry priority was spread throughout the watershed, with sub-watersheds 1-4, 16, 17, and 19-26 rated medium-high to high priority. From the riparian buffers analysis, 10 sub-watersheds were grouped into medium-high or high priority, including sub-watersheds 1, 3, 5, 10, 15, 17, 18, 23, 24, and 26. After weighting the six parameters, 10 sub-watersheds (1, 3, 5, 10, 14, 17, 18, 23, 24, and 26) were identified with overall medium to medium-high priority and incorporated into Phase II.

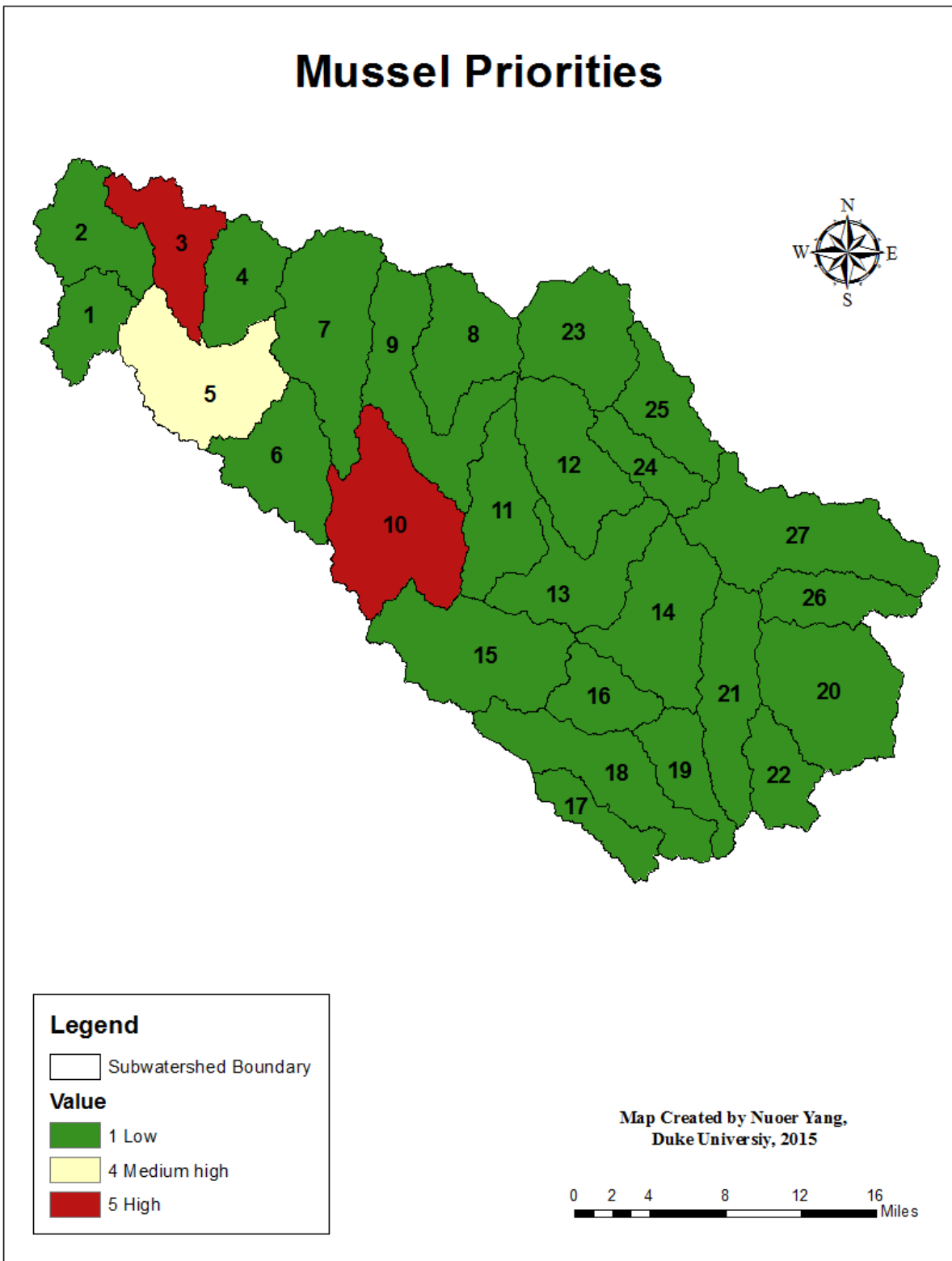


Figure 8. Mussel sub-watershed priority analysis.

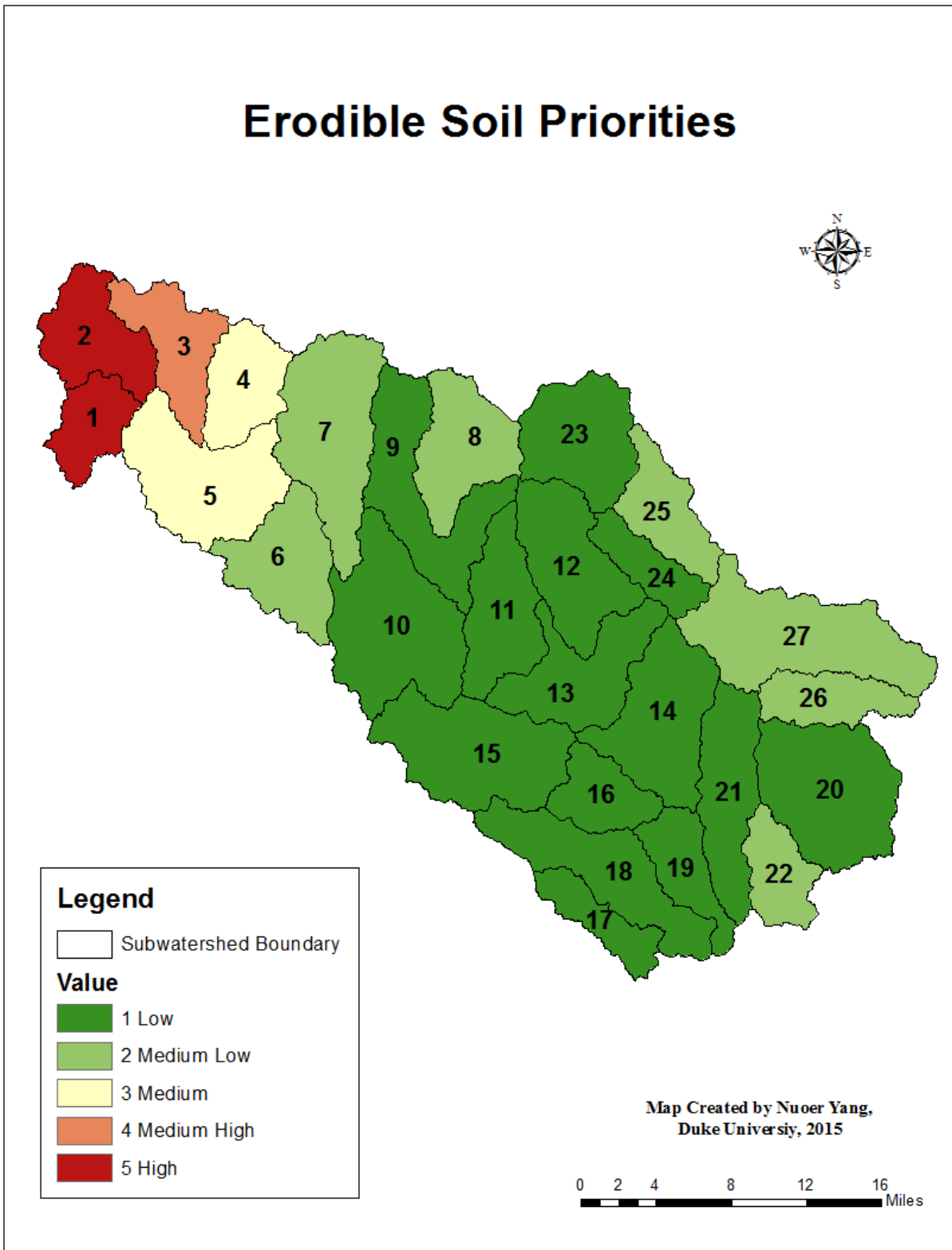


Figure 9. Erodible soil priorities based on soil K factor.

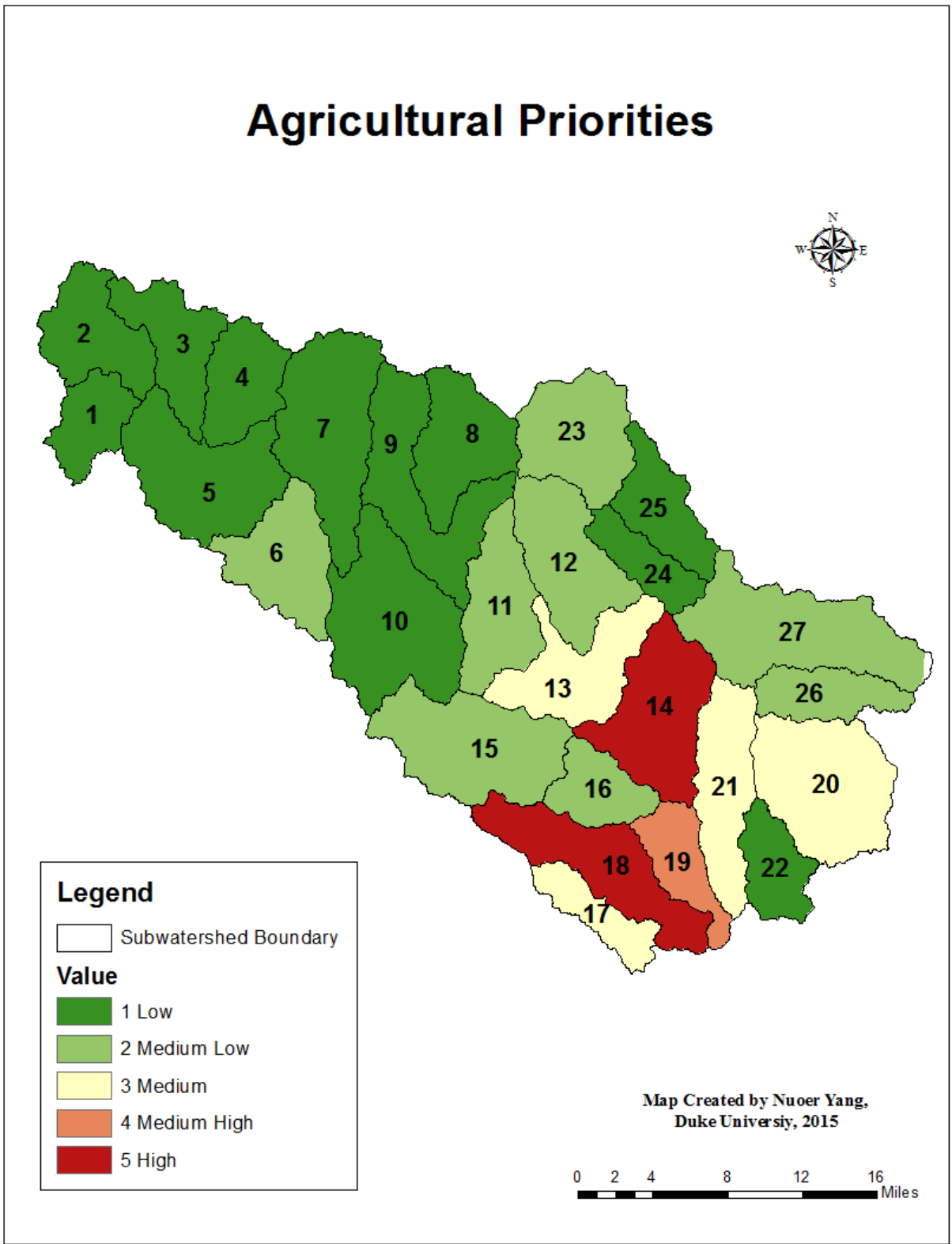


Figure 10. Site analysis of agriculture indicator. Majority of the watershed yielded low priority.

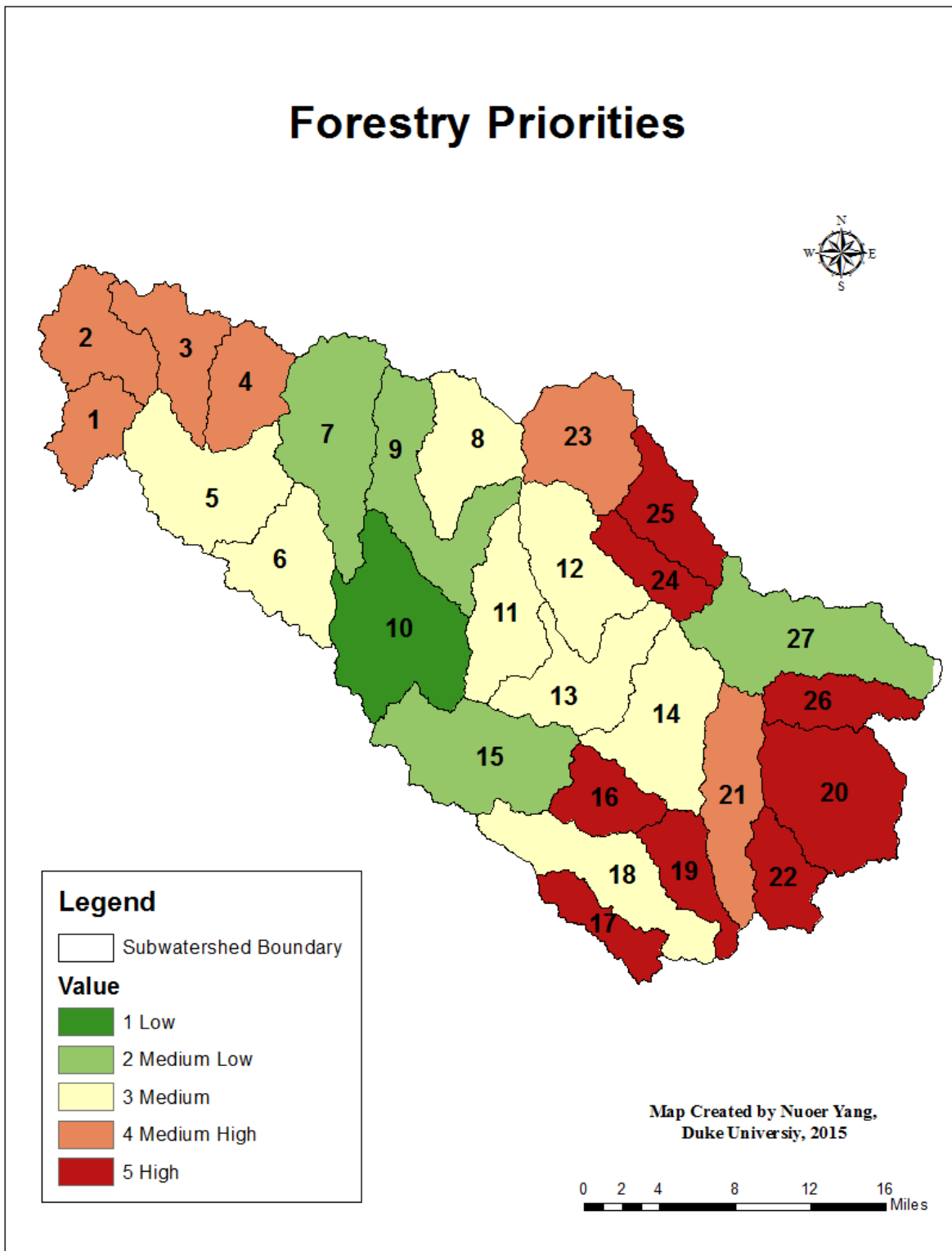


Figure 11. Forestry site analysis. High priorities focused on the southeastern end of the watershed.

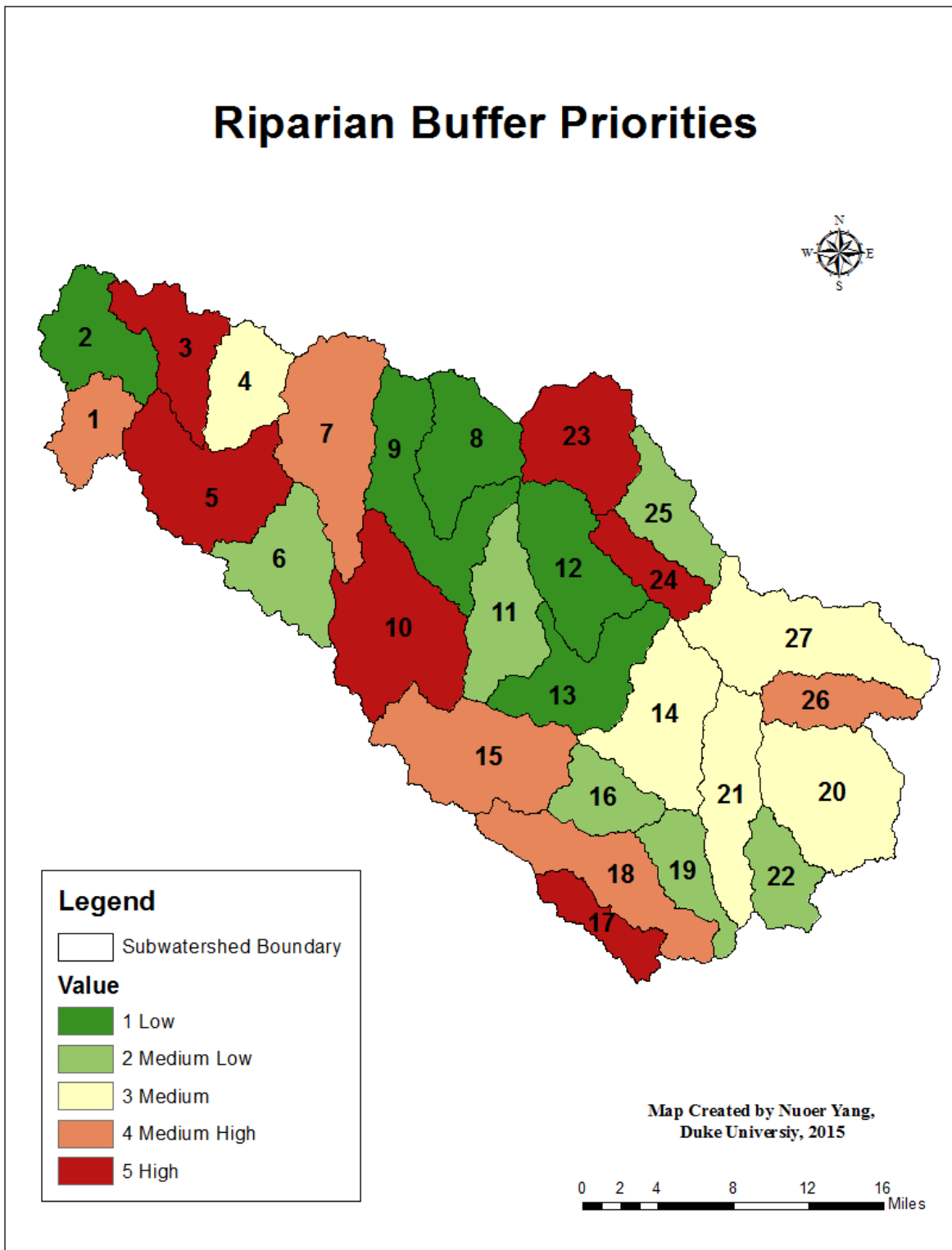


Figure 12. Riparian buffer analysis. Areas of interest/concern occurred in the southern and western parts of the watershed.

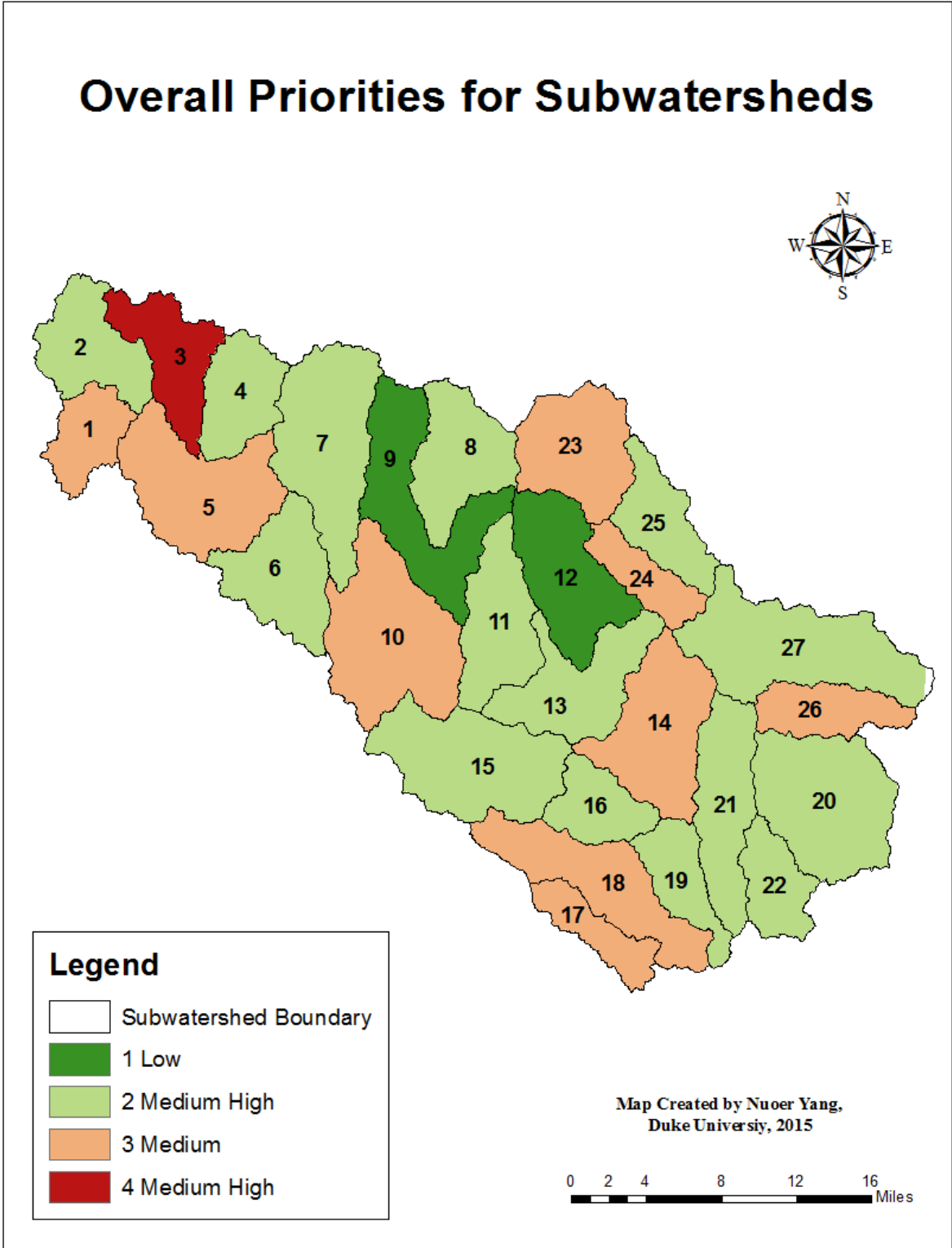


Figure 13. Phase I sub-watershed priority ranking.

## *Phase II: Detailed Watershed Assessment*

Focusing on the 10 identified sub-watersheds from Phase I, the PLOAD model found highest nitrogen loading values for sub-watersheds 14, 17, and 23, with annual rates ranging from 0.62-1.42 lbs/acre. Compared to nitrogen, phosphorous loading revealed similar results with the addition of sub-watershed 24. Annual loading rates for phosphorous ranged from 0.43-0.64 lbs/acre. The state rule for nutrient management strategy require that proposed new development activities not exceed 4 lbs/year and 0.4 lbs/year for nitrogen and phosphorous respectively (N.C. 2001). Comparing the PLOAD values to the regulated standards for new development, nitrogen shows indication of reduction in nutrient loading, whereas phosphorous stills requires much needed work to reduce annual loading rates.

Figures 16-19 present the results of each parameter from the RUSLE model. In the ten selected watersheds, sub-watershed 10 has the highest soil sediment loads, followed by 23, 5, and 14. When all parameters are combined, sub-watersheds 10 and 23 show greatest annual sedimentation, with values of 24,250 tons/acre and 17,127 tons/acre respectively. Sub-watersheds 5 and 14 also resulted in high sedimentation rates at 14,150 tons/acre and 13,942 tons/acre respectively.

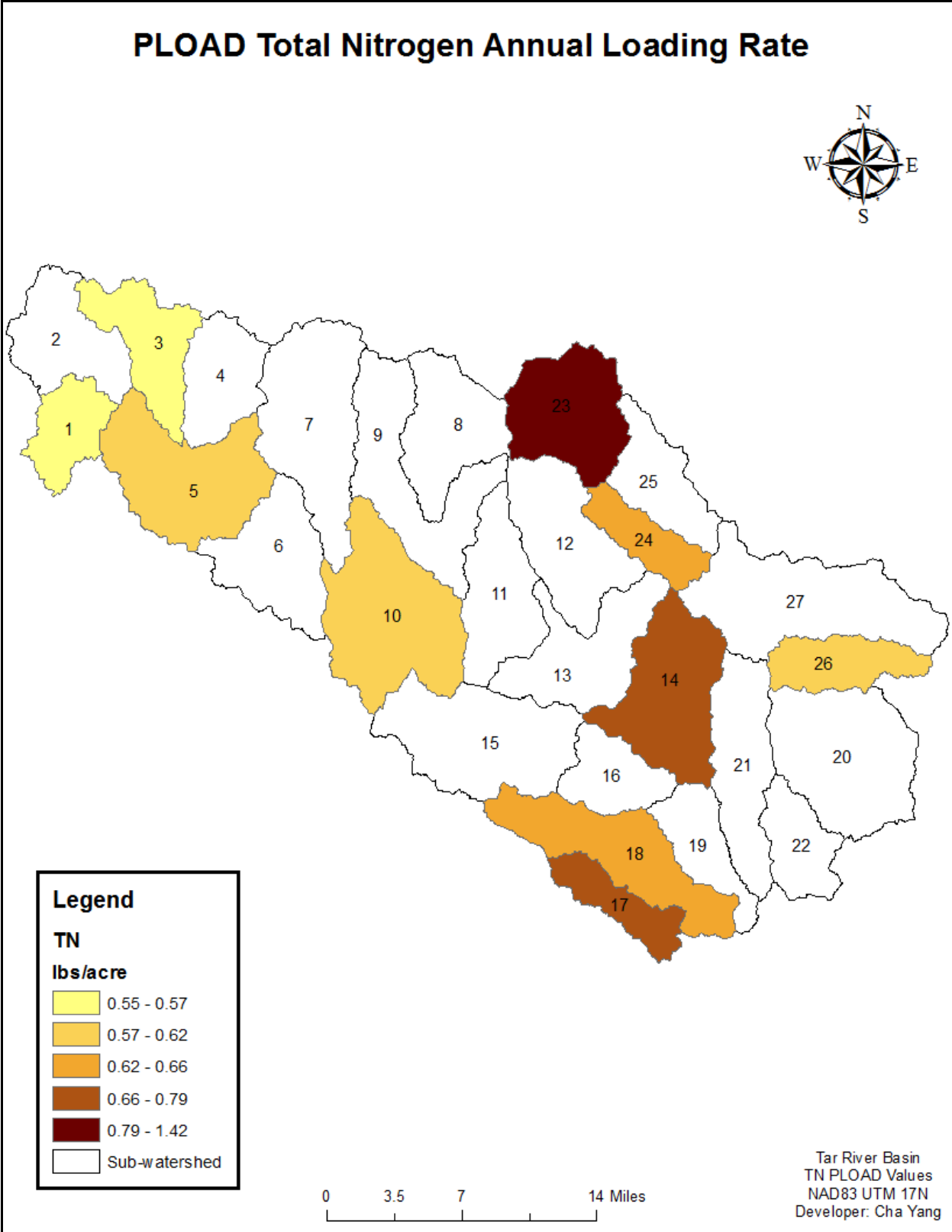


Figure 14. Total Nitrogen loading rates from PLOAD model.

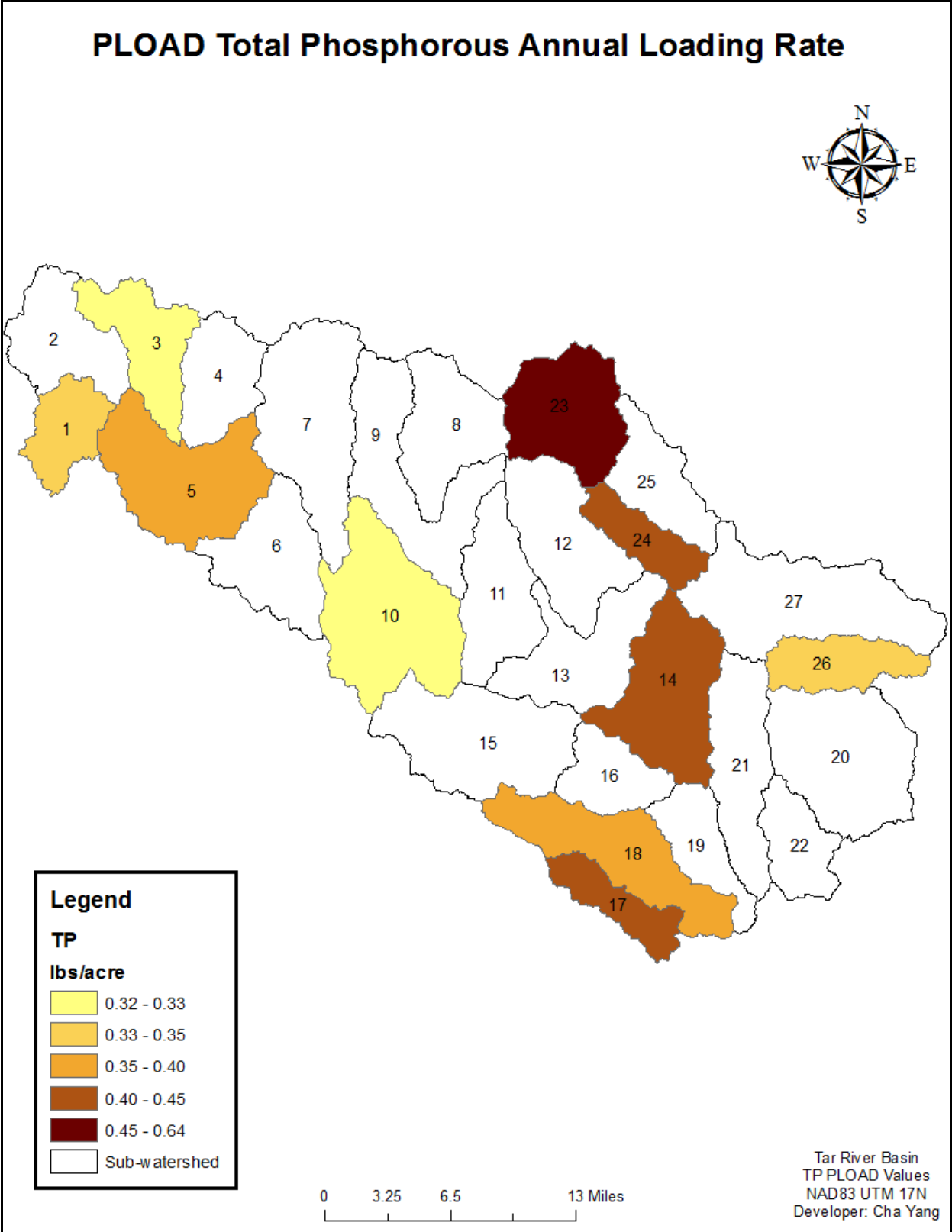


Figure 15. Total Phosphorous loading rate from PLOAD model.

# R Factor for the Upper Tar River Watershed

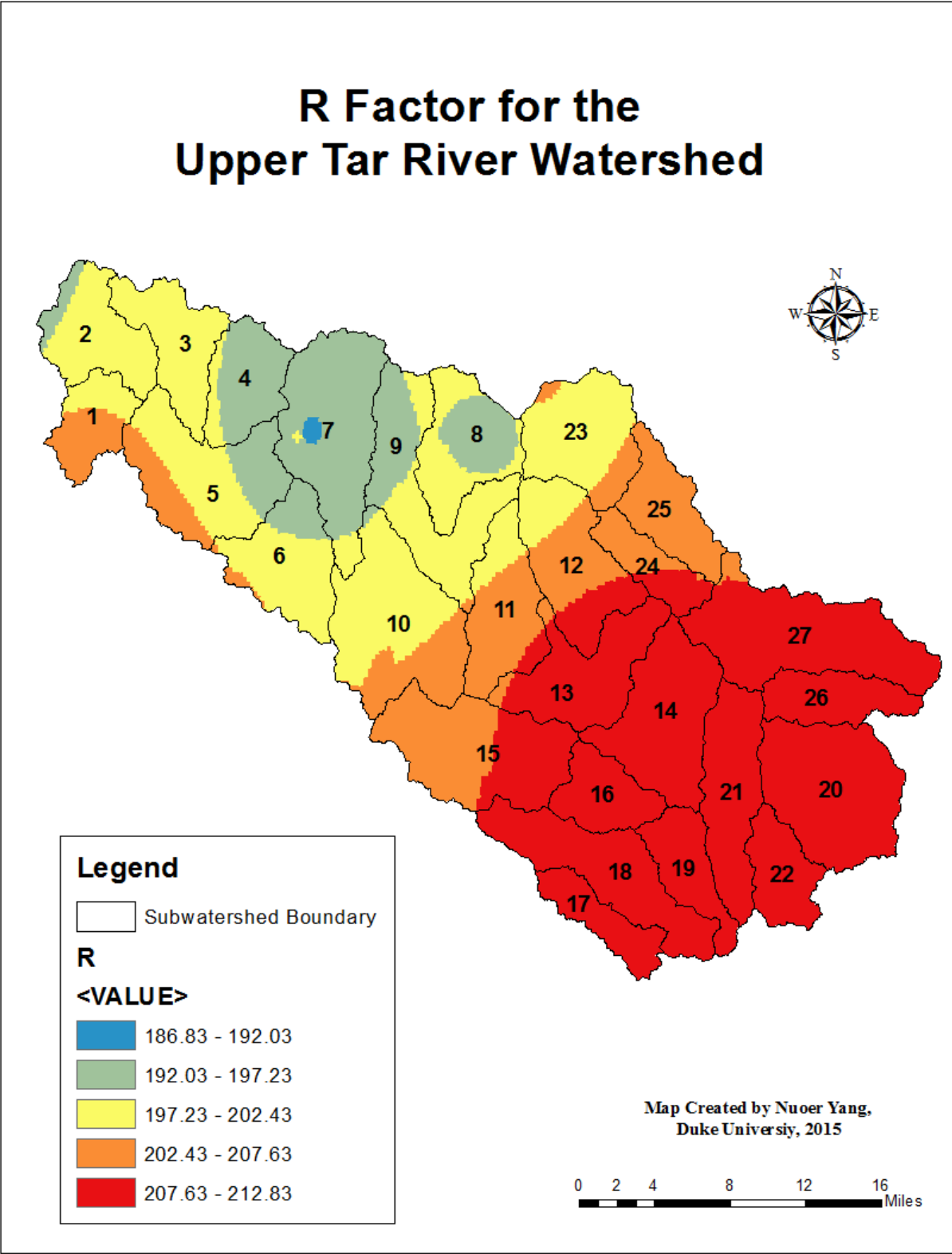


Figure 16. RUSLE R factor distribution.

# LS Factor for the Upper Tar River Watershed

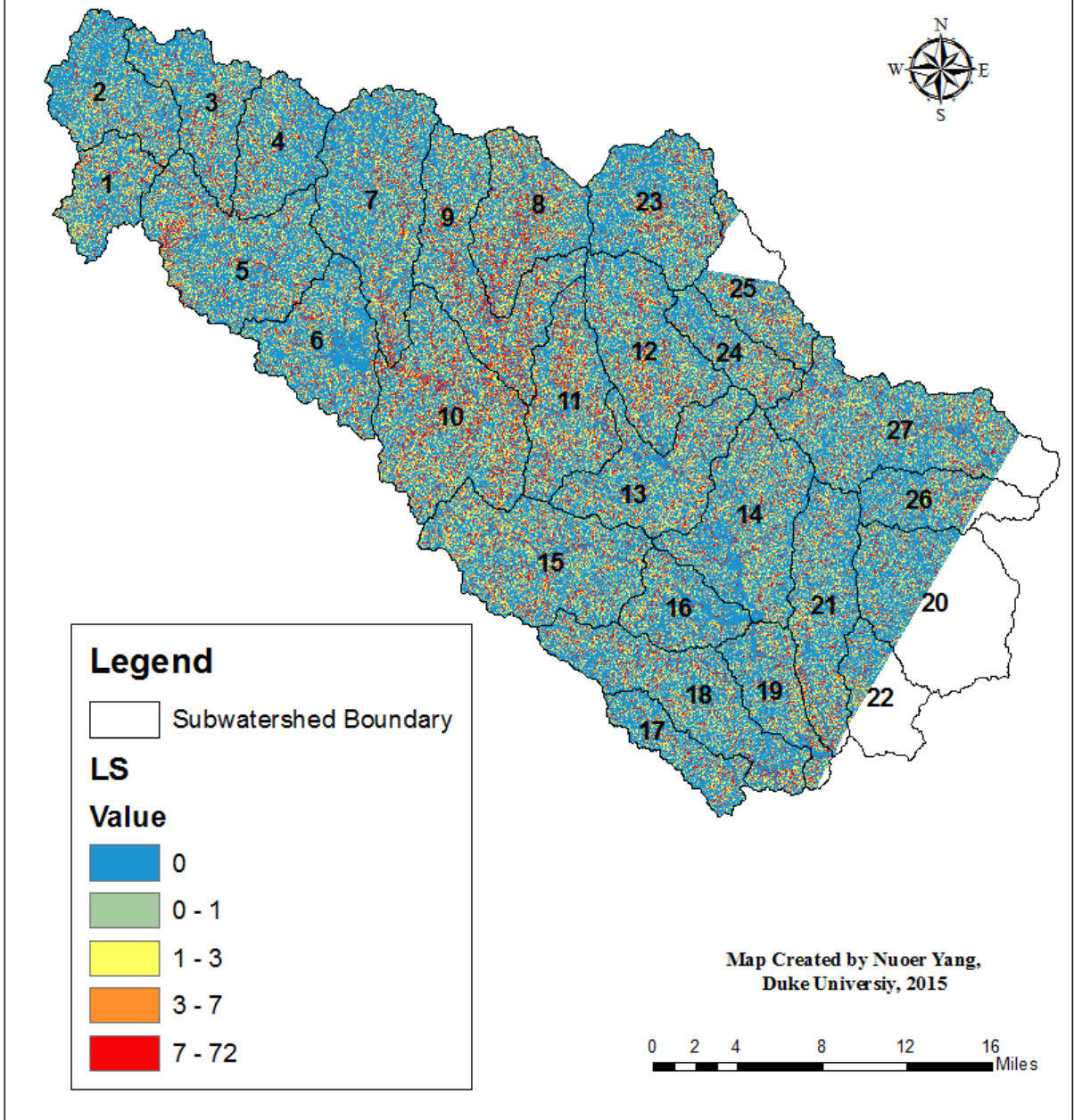


Figure 17. LS factor analysis for RUSLE model.

# C Factor for the Upper Tar River Watershed

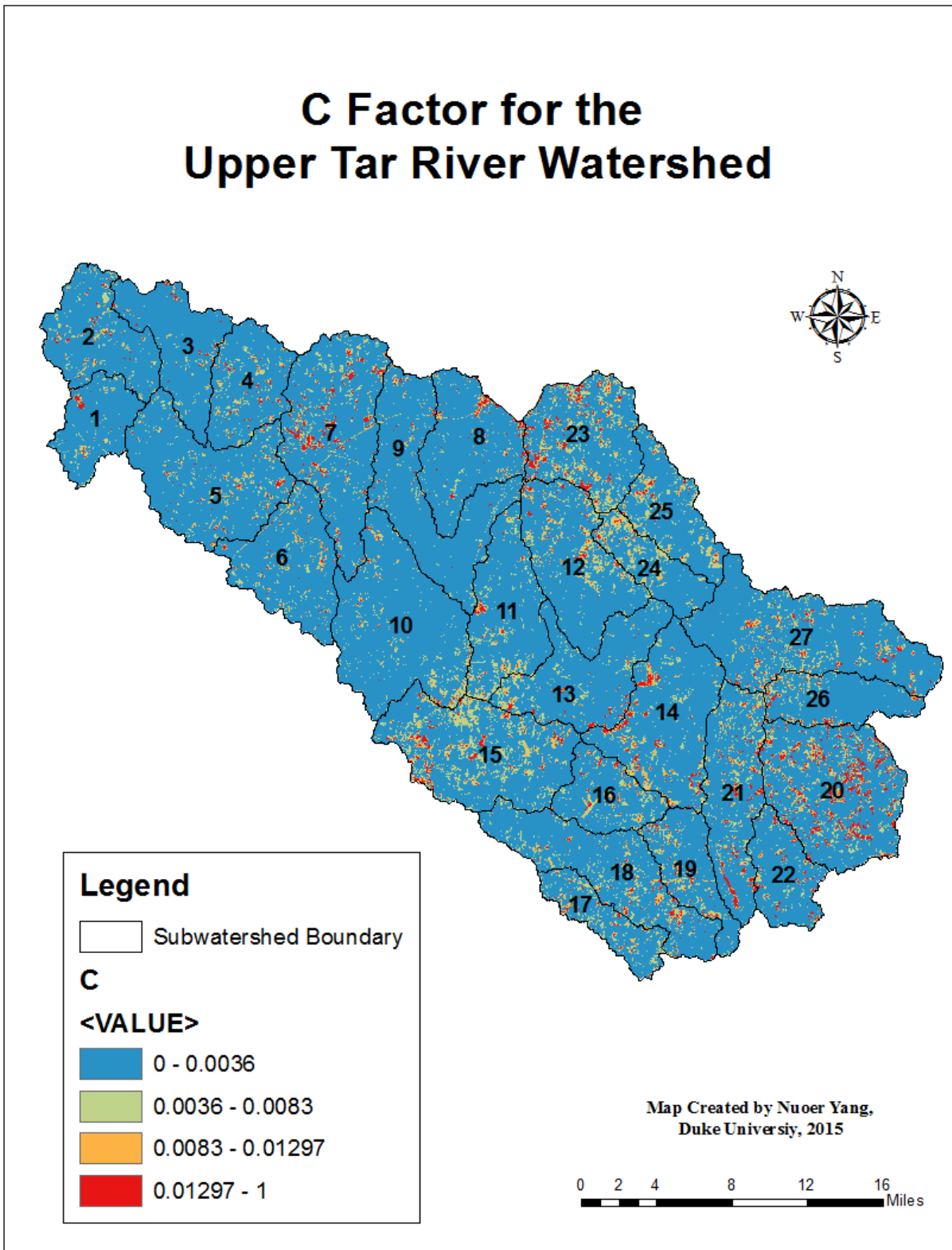


Figure 18. C factor analysis for RUSLE model.

# The Upper Tar River Watershed Sedimentation RUSLE Analysis

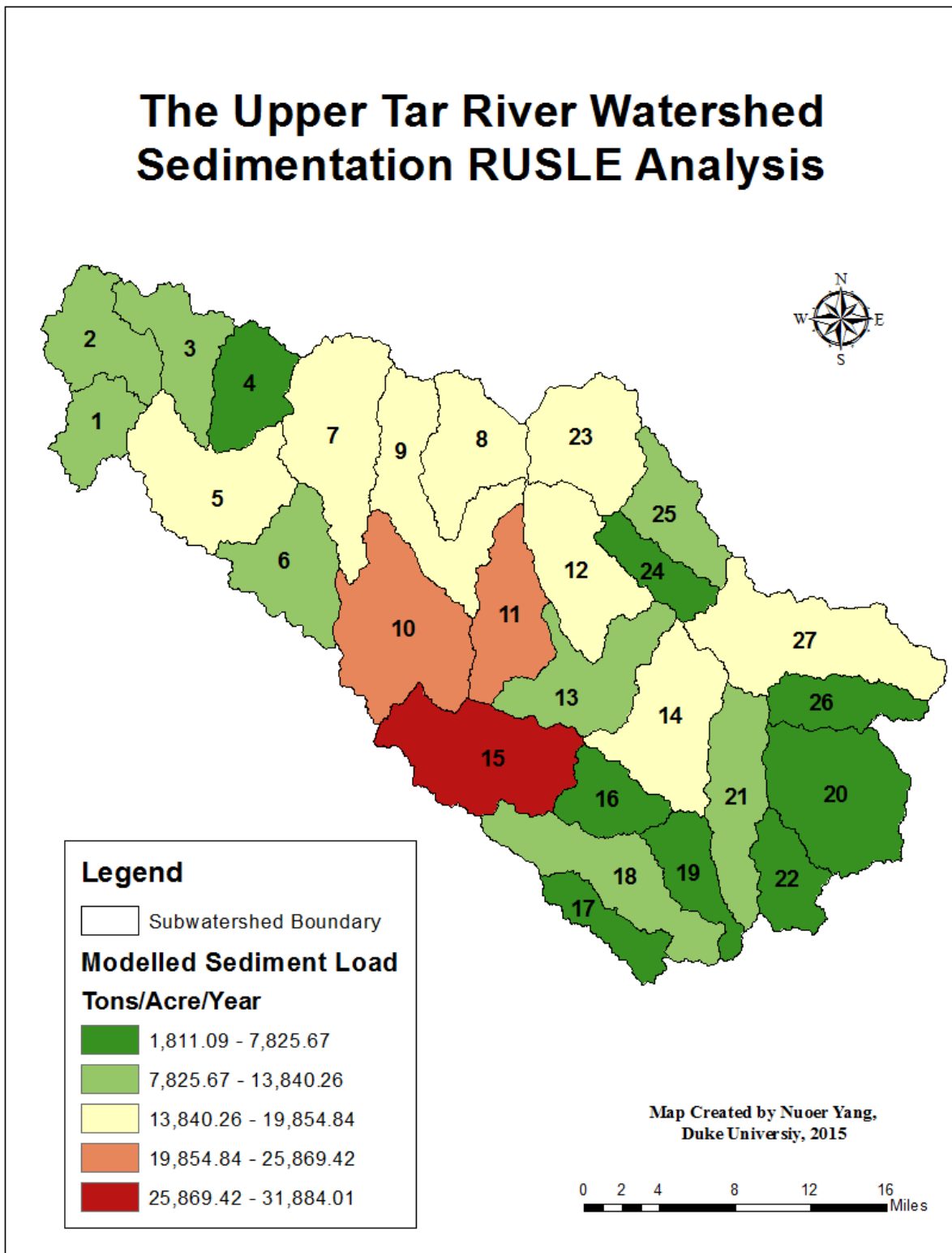


Figure 19. RUSLE sedimentation analysis.

Five stream segments were identified from the stream site assessment, one in Franklin County (sub-watershed 14) and the rest in Granville County (sub-watersheds 3 and 10). Sub-watersheds 10 and 14 contained one stream segment each and sub-watershed 3 contained three stream segments. Fox Creek, in sub-watershed 3, was divided into two segments because the creek exits TRLC conservation easement property before re-entering a different TRLC property. All creeks in sub-watershed 3 were third order streams, while the remaining two streams were first order, or headwaters.

After ranking the stream sites, the lower portion of Fox Creek in sub-watershed 3 received the highest score of 6.4 and thus the highest priority. Shelton Creek in sub-watershed 3 ranked the next highest in priority, followed by the stream in sub-watershed 14, the upper portion of Fox Creek, and lastly the stream in sub-watershed 10, as shown in Figure 20. Elements contributing to the lower half of Fox Creek scoring as highest priority included longest stream segment, high mussel recruitment potential, medium-high soil erodibility, and low riparian buffer capacity. Although Fox Creek splits off between two properties, because both segments are maintained by TRLC, combining both sites into one optimizes the possibility of generating the most credits for a single site.

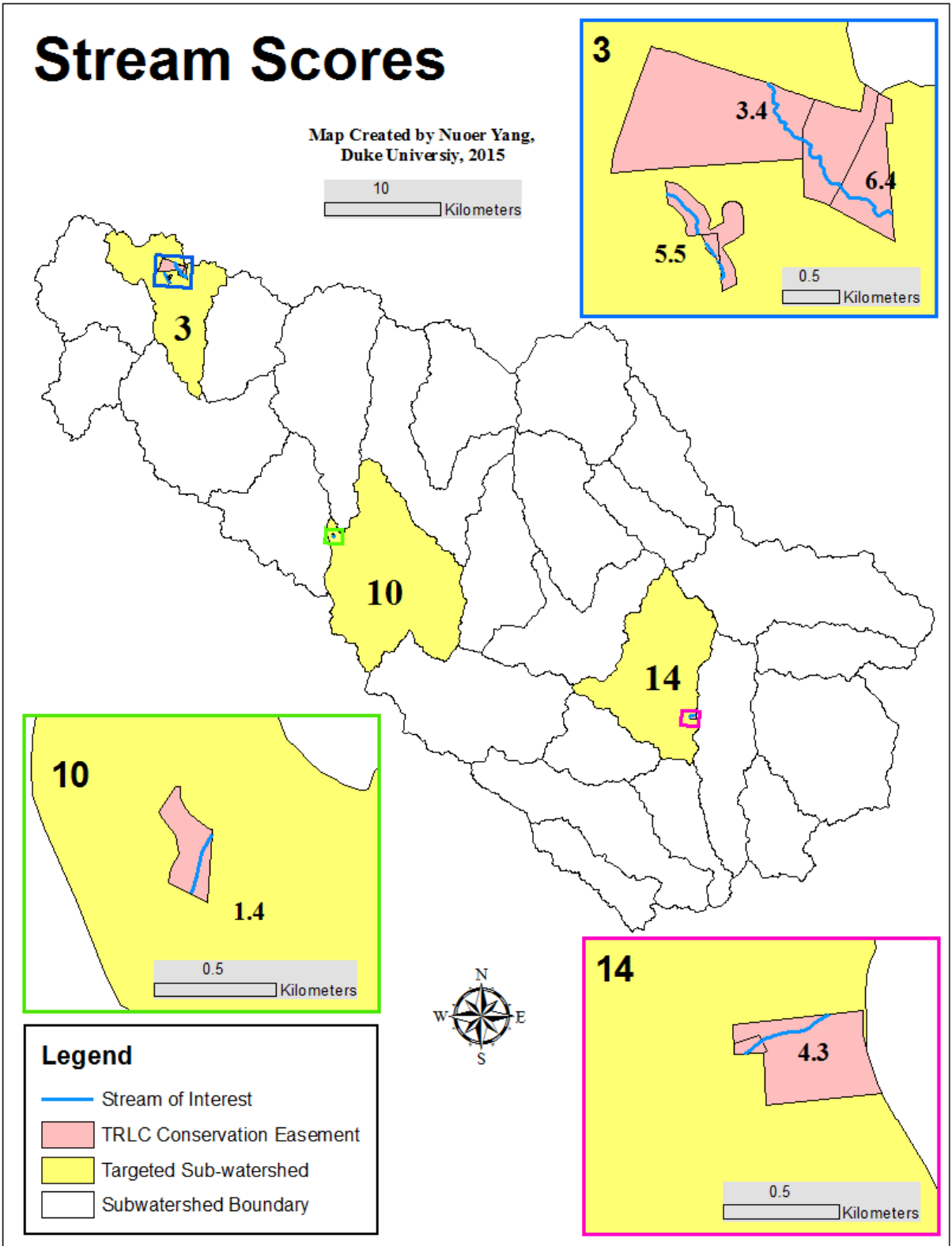


Figure 20. Stream score for selected streams in the Tar River basin.

## *Objective 2 Pitfalls and Liabilities*

Only one land trust gained attention and consideration in some published work related to mitigation banking. The Environmental Trust (TET) located in San Diego, CA is known for its downfall in mitigation bank activities resulting in the organization filing for bankruptcy in 2005, exceeding \$13 million in unperformed obligations (Teresa 2006). The business model of the land trust focused on acquiring land but lacked emphasis to maintain high environmental quality of sites. Land stewardship involved the simple tasks of putting fences up and maintaining them where funding was available, picking up visible litter, and performing drive-by monitoring visits (Teresa 2006). This suggests lack of action taken to ensure that sites were adequately restored or preserved with the intention to promote ecological integrity. Applying fixed estimation costs, TET often underbid against the competition resulting in acquisition of land while lacking funds to adequately restore sites (Teresa 2006). Whereas site cost estimation should vary from site to site, TET applied a fixed cost of dollar per acre and failed to adjust for inflation. The land trust also failed to maintain records of some conservation easements, transparency on projects and finances, and properly defined obligations and responsibilities for long-term monitoring and management (Teresa 2006). In this study five factors leading to the fall of TET were identified:

- Failure to create and perform a realistic business plan;
- Unclear definitions and guidelines of “best management practices for habitat stewardship”;
- Lack of state and federal intervention;
- Poor quality financial management; and
- Noncompliance with logical business practices.

TET’s downfall provides four theme lessons to consider before creating a mitigation bank covered in Tables 7-10. Table 7 focuses on planning design and variables to consider when designing a bank. Plans should present clear objectives and show how the bank is prepared to handle project tangents and long term management. Success of a bank requires professional staffing and strong supervision. Table 8 targets financial assurance to support both the restoration activities and long-term monitoring. Funding is easily acknowledged for jumpstarting a business enterprise, but strategic funding plans require financial assurances for long-term monitoring and security from site degradation or failure. Table 9 considers the expertise required to manage the environmental, business, and legal aspects of mitigation banking. Land trusts may not have the adequate personnel to complete each step of the banking process or may just not have enough staff in general to fully manage a bank. Utilizing the professional expertise from other organizations and firms increases the level of experience to effectively complete the bank and generate credits. Partnering with other organizations can also reduce the amount of stress and workload per group and increase project effectiveness. Table 10 focuses on no net loss and preventing site degradation. Challenges to mitigation banks include long-term monitoring and restoring natural stream functions loss from dredging or filling. Understanding the time lag between restoration activities and ecological function return and planning accordingly can improve zero-net loss.

Table 7. Planning Design.

<ul style="list-style-type: none"> <li>• Establish clearly defined goals and objectives that are both quantitatively measurable and realistic.</li> <li>• Create baseline conditions to measure progress of restoration activities.</li> <li>• Incorporate stakeholders’ interest in the planning process.</li> <li>• Include adaptive management</li> </ul>	<ul style="list-style-type: none"> <li>• Teresa 2008; Wetland 2012; Kusler 2009</li> <li>• Teresa 2008; Kusler 2009</li> <li>• Wetland 2012; Teresa 2008</li> <li>• Carroll et al. 2008; Teresa 2008; Kusler</li> </ul>
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<p>accounting for site degradation, invasive species infestation, fluctuating water levels, and on/off-site impacts (toxic runoff, sedimentation, etc).</p> <ul style="list-style-type: none"> <li>• Identify current and future trends in development, regulations, etc. that will influence any aspect of the mitigation bank.</li> <li>• Maintain supervision accountability.</li> <li>• Clearly articulate the responsibilities of parties and individuals.</li> <li>• Maintain transparency with stakeholders and regulators.</li> </ul>	<p>2009; Wetland 2012</p> <ul style="list-style-type: none"> <li>• Teresa 2008</li> <li>• Wetland 2012; Hallwood 2007</li> <li>• Kusler 2009; Hallwood 2007</li> <li>• Wetland 2012; Teresa 2008</li> </ul>
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Table 8. Financial Assessments.

<ul style="list-style-type: none"> <li>• Acquire adequate funding to support the entirety of the project, from site assessment and restoration to long-term monitoring; upfront investments is required to confirm financial security.</li> <li>• Establish financial assurances to fund the completion of the mitigation project in the chance of project failure.</li> <li>• List all costs involved in the mitigation process (i.e. employee payment, contract services, materials and equipment, overhead costs)</li> <li>• Factors to consider when developing/reviewing costs estimates: quality of source data, completeness of assessment, inflation, potential project failure.</li> <li>• The Property Analysis Record (PAR) developed by the Center for Natural Lands Management is often used to assess costs estimates.</li> </ul>	<ul style="list-style-type: none"> <li>• Wetland 2012; Carroll et al. 2008; Kusler 2009; Scodari et al. 2011</li> <li>• Wetland 2012; Scodari et al. 2011</li> <li>• Carroll et al. 2008; Scodari et al. 2011</li> <li>• Scodari et al. 2011</li> <li>• Slee 2000; Teresa 2008; Wetland 2012</li> </ul>
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Table 9. Multi-sector Expertise.

<ul style="list-style-type: none"> <li>• Provide expertise from both the environmental, business, and legal sector to cover all aspects of mitigation banking.</li> <li>• Maintain adequate number of staffing to ensure effective site monitoring and</li> </ul>	<ul style="list-style-type: none"> <li>• Carroll et al. 2008; Robertson 2009; Kusler 2009</li> <li>• Carroll et al. 2008</li> </ul>
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<p>minimized work overload.</p> <ul style="list-style-type: none"> <li>• Establish strong relationships with clients and acquaintances from other firms/organizations.</li> </ul>	<ul style="list-style-type: none"> <li>• Robertson 2009;</li> </ul>
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Table 10. No Net Loss/Site Degradation.

<ul style="list-style-type: none"> <li>• Monitor areas using multiple ecological equivalency tests to measure function loss.</li> <li>• Consider stream functions/values of interest and the time for functions to return after restoration.</li> <li>• Minimize time delay between initiating and completing restoration activities</li> <li>• Re-establishment of ecosystem functions has a time delay to achieve “full functional equivalency.”</li> <li>• Control site degradation from poor vegetation establishment and succession of invasive species.</li> <li>• Different vegetation cover can influence animal site preference.</li> </ul>	<ul style="list-style-type: none"> <li>• Turner et al. 2001</li> <li>• Bendor 2009; Kusler 2009; Turner et al. 2001</li> <li>• Bendor 2009</li> <li>• Bendor 2009</li> <li>• Gardner and Radwan 2005; Kusler 2009; Hallwood 2007</li> <li>• Turner et al. 2001</li> </ul>
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### ***Objective 3 Business Plan***

The largest costs going into creating a mitigation bank include purchasing land, construction, mitigation plan, and consulting fees (Bylow 2015). Other expenses include administration, monitoring along multiple checkouts throughout the bank’s lifetime, site maintenance, and perpetual stewardship. While costs vary from site to site, overall project costs can range from \$85-250/linear foot for stream mitigation banks (Bylow 2015). The costs for NCEEP projects fall around the same range from \$165-271/linear foot for design-build or design-bid-build projects (Dumas and Templeton 2007). Total costs of projects vary depending on the size of projects. From EEP values, projects ranging from 1,400 - 13,000 linear feet of

stream restoration or enhancement required \$378,766 - \$2,145,735 of funding respectively (Dumas and Templeton 2007).

The costs to restore the stream sites identified from Objective 1 range from \$73,400-\$980,000 (Appendix). As the smallest of the five projects, stream site 1 in sub-watershed 10 requires the least funding for restoration and generates the least amount of credits. The upper portion of Fox Creek in sub-watershed 3 yielded the highest costs as the largest project. To generate the most revenue, the ideal situation would involve spending the least amount of funding required to effectively restore the stream complimented with a high-demand market to receive the greatest return per stream credit sold. Because this study targeted conservation easements owned by TRLC, actual costs may be closer towards the lower end of the spectrum, increasing the chances of seeing a larger return in revenue.

Stream credits in North Carolina sell at around an average price compared to the national scale. EEP's fee schedule for stream credits range from \$289-\$381 per linear foot. The City of Charlotte Umbrella Stream and Wetland Mitigation Bank, which works in the Catawba and Rocky Rivers, sells stream credits at higher values from \$375-\$484 per linear foot (City 2015). Using the average of these values, \$384/linear foot, selling all credits per project can yield return anywhere from \$330,000-\$1.5 million (Appendix). Similar to project costs, return values are smallest for stream site 1 in sub-watershed 10 and largest for site 5 (Fox Creek) in sub-watershed 3. After deducting the cost invested into each project, total revenue ranges from \$116,000-\$1.2 million (Appendix). The influx of revenue pulses are based on the credit release schedule designed by the regulatory agencies and the rate at which credits are sold. Market demand and success of negotiations also influence monetary return and may increase or decrease revenue returns.

External funding sources help not only to reduce project costs, but also increase economic return as no internal funding is spent towards mitigation projects. Potential funding sources came from federal, state, and private entities. These programs vary in their interests, from promoting fish and wildlife, improving water quality, to conservation. Overall, six programs were identified that may serve as funding sources for securing a mitigation bank.

Table 11. Funding sources to promote mitigation banking.

<b>Source</b>	<b>Program Description</b>	<b>Link</b>
National Fish and Wildlife Foundation	Provides competitive grants toward improving fish, wildlife, and plants and their habitats. Multiple grants are available but may vary in their specifics to subject and location.	nfwf.org
Partners for Fish and Wildlife	“Provide technical and financial assistance to private landowners and Native American Tribes interested in voluntarily restoring or otherwise improving native habitats for fish and wildlife on their lands” (Partners 2012).	cfda.gov
Clean Water Management Trust Fund	State grant program designed to support conservation and protection of surface waters in North Carolina.	cwmtf.net
NCDOJ Environmental Grants	Grant awarded by the Attorney General to improve water quality through preserving land along rivers, restoring wetlands, cleaning hog lagoons, and developing alternative uses for hog waste.	ncdoj.gov
North Carolina Wildlife Habitat Foundation	Private grant organization supporting the “acquisition, management, and protection of wildlife habitat within the state of North Carolina and promoting conservation	ncwhf.org/grants

	education for the benefit of future generations” (Grants 2015).	
Conservation Trust for North Carolina Loan Program	Supports local land trusts with low interest bridge loans to help land trusts protect threatened properties.	ctnc.org

In the Tar River basin, two private banks currently exist that provide riparian buffer and nutrient offset credits. One is situated outside of the study area in Edgecombe County and the other in Person County. The Tar River Headwaters Bank, developed by Mogensen Mitigation, Inc., was signed into agreement with the EEP in 2013 (Mogensen 2013). The bank lies on a 228-acre farm within 1 mile from the Person-Granville county line (Mogensen 2012). As a Nutrient Offset and Riparian Buffer mitigation bank, the Tar River Headwaters Bank is regulated by the Department of Water Quality (N.C. 2010) and extends from an umbrella mitigation bank serving multiple bank sites aside from the site in Person County. Aside from mitigation banks, EEP lists one LWP within the Tar River basin. Fishing Creek surrounds the City of Oxford and presents multiple environmental concerns mentioned by the local community (W.K. Dickson 2012). The basin also holds many targeted local watersheds, areas of concern for planning and project implementation.

## **Discussion**

One challenge to mitigation banking is gauging the present and future demand for stream credits. Utilizing population growth data provides some insight to predicting spatial trends in population. The Office of State Budget and Management provides county projections on a 10 year scale. Within the four counties assessed, from 2010-2020 population is expected to decline in Person and Vance County, have low in-migration in Granville County, and medial growth in Franklin Country (County 2015). Moving another 10 years, from 2020-2030, Vance County is expected to continue declining in population, Granville and Person Counties are projected to have low, net in-migration, and Franklin County continues to grow at a medium rate (County 2015). Although Raleigh is expected to grow rapidly, a precaution is warranted for Granville, Vance, and Person counties. Franklin County holds the greatest prospect of the four counties to pursue mitigation activities. While this discussion focuses on population trends, it is also important to assess other factors that may drive the economics of mitigation banking. Additionally, no known banks sit within Franklin County, giving TRLC greater mobility to serve in the county.

Much of the literature argues that mitigation banking is often a partnered endeavor. Incorporating the expertise of different organizations and companies can assure greater effectiveness to project management and completeness throughout the bank's lifetime. NCEEP often outsources mitigation projects to private banks throughout various steps of a bank's development. In 2011-2012, 49 contracts were signed by NCEEP with private firms (Annual 2012). Of the 49 contracts, 12 included full delivery while the other 37 only focused on one aspect of the project (e.g. construction, monitoring, design, etc.). Benefits from establishing

partners include reducing the risk, liabilities, and workload for the organization, in addition to receiving expertise from groups familiar with the mitigation process (Wetland 2012). While one organization may not have the complete expertise or staff to manage one aspect of the bank, dividing the work ensures ecological and economic integrity of the bank and prevents financial tragedies.

Aside from taking the lead role in mitigation banking, other options are available for consideration when challenges occur. The Land Trust Alliance contains a handbook on wetland and stream mitigation banking, which includes discussion on roles that land trusts can take to guide the mitigation process, from providing guidance in the site selection process to commanding long term stewardship of properties after credits have been sold (Wetland 2012). Taking up these roles would grant TRLC the ability to direct decision-making that ensures the protection of wildlife habitat, in addition to connecting with consulting firms and banks that typically do not communicate with land trusts.

Partnering with other organizations may also involve engaging in other types of mitigation practices. In North Carolina, a growing trend revolves around nutrient offset and riparian buffer mitigation. These forms are regulated by the Department of Water Quality (DWQ) with payments handled by EEP. Both mitigation activities are currently only applicable to nutrient sensitive waters, serving as nutrient management strategies to offset nitrogen and phosphorous loading into waters, and require formation under an umbrella mitigation bank (Merritt 2013). An umbrella mitigation bank is defined as an “instrument for the establishment and operation of multiple bank sites” (ACE 1995). Because TRLC does not operate multiple bank sites, performing the above activities on conservation easements will require some partnership with an entity already established as an umbrella mitigation bank. Noted earlier, the

Tar River Headwaters Bank is an umbrella bank and could serve as a potential partner to create nutrient offset and riparian buffer credits.

This study targeted streams with conservation easements owned by TRLC. Other potential sites to consider include 303d streams and their tributaries. These streams include those that do not meet water quality standards affirmed by the Clean Water Act and must be reported by states (Federal 2002). Within the study area, two 303d streams are present and situate in Franklin County, which include Crooked Creek and Sandy Creek (Category 2014). Targeting these stream and their tributaries can assist with improving ecological function through capturing nutrient runoff from surrounding land practices. From Figure 21, an analysis identified potential tributaries to the 303d streams for mitigation activity based on the methods from Objective 1.

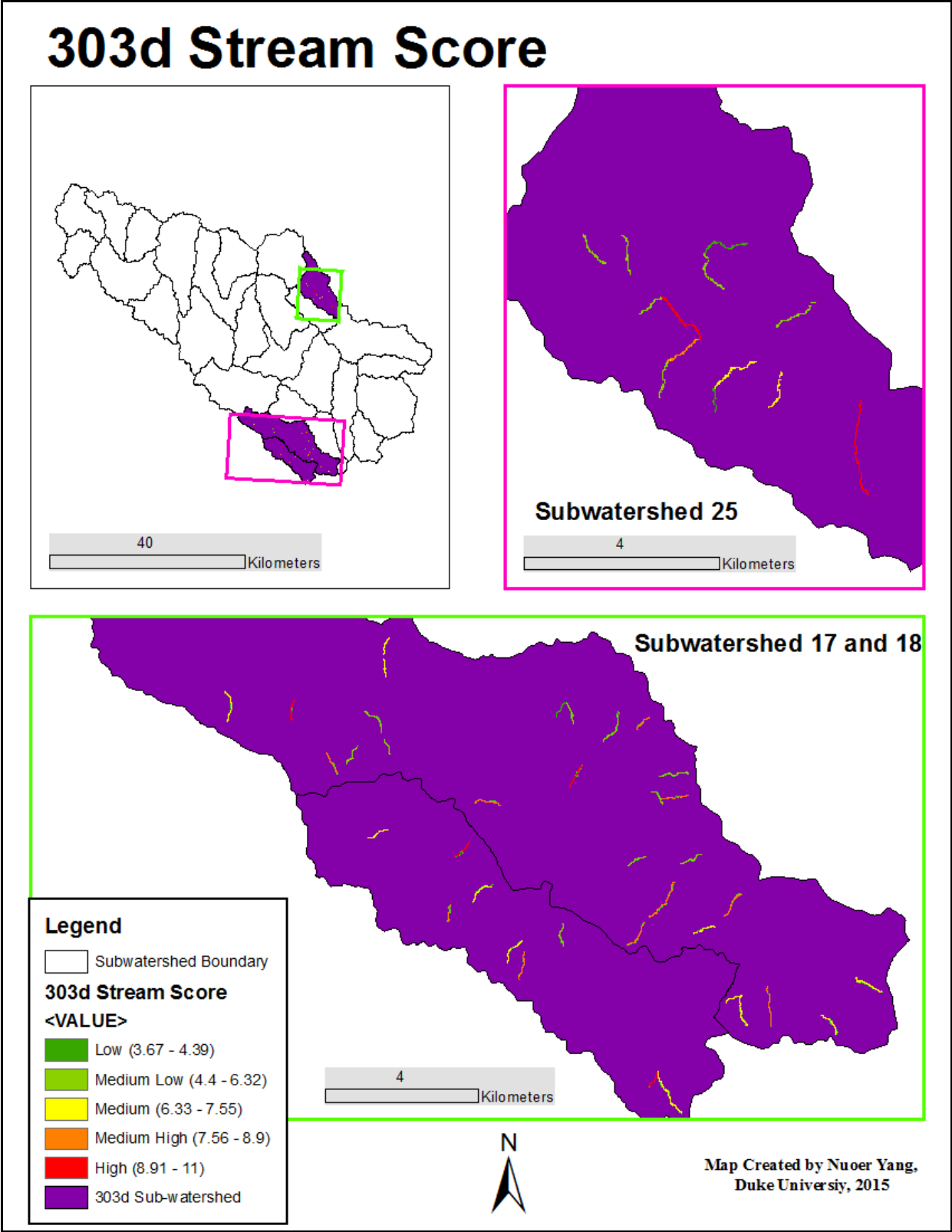


Figure 21. Stream score for 303d streams in the Tar River basin.

## Conclusion and Recommendations

Mitigation banking can serve as tool to receive additional funding to improve the ecological integrity of properties under conservation easements. Many financial and legal risks come with the business, but identifying partnerships can help alleviate these risks. Understanding the factors driving mitigation banking in the Tar River will be crucial for deciding whether the benefits outweigh the costs. Along with population trends, it will be important to identify other factors that will influence mitigation activities, such as public mindset, long- and short-term impacts, etc. Expanding site selection to areas outside of TRLC conservation easements present another outlet to consider with expanding the business plan. Recommendations we wish to highlight from the study are:

- Designate stream site 2 in sub-watershed 14 and both segments of Fox Creek in sub-watershed 3 as greatest potential for restoration and economic gain and consider these first.
- Consider as potential partners those consulting firms and/or other organizations familiar with mitigation banking since they can assist with establishing and ensuring the sustainability of the business.
- We recommend that TRLC avoid becoming overwhelmed by a mitigation project and rather that they consider a smaller initial role until the process becomes familiar.

## **Acknowledgements**

Thanks to TRLC for providing the opportunity to work with them and develop a plan to assist in their progress as a land trust. The authors thank their advisers, Bill Ross and Dave Hinton, for their guidance and comments to the project and revisions. Thanks to North Carolina Natural Heritage Program for allowing access to data. Thanks to Dempsey Benton, Melissa Chernick, and Martin Doyle for their contributing comments and suggestions. Thanks to Peter Cada and John Fay for assistance in GIS.

## Reference

- ACE, US. "Federal guidance for the establishment, use and operation of mitigation banks." *Federal Register* 60 (1995): 228.
- Advanced Hydrologic Prediction Service*. National Ocean and Atmospheric Administration, National Weather Service, 2014. Web. 24 April 2014.
- Amsalu, T., & Mengaw, A. (2014). GIS Based Soil Loss Estimation Using RUSLE Model: The Case of Jabi Tehinan Woreda, ANRS, Ethiopia. *Natural Resources*, 2014.
- Annual Report 2011-2012*. Ecosystem Enhancement Program, 2012. Web. 10 March 2015.
- Bendor, Todd. "A Dynamic Analysis of the Wetland Mitigation Process and its Effects on no Net Loss Policy." *Landscape and Urban Planning* 89 (2009): 17-27. Web. 15 January 2015.
- Bradford, Ben. *Charlotte and Raleigh Lead U.S. in Projected Population Growth*. WFAE, 2014. Web. 8 February 2015.
- Bylow, Tiffani. "Stream Mitigation Costs." 2 Mar. 2015. E-mail.
- Carroll, Nathaniel, Fox, Jessica, Bayon, Ricardo. *Conservation & Biodiversity Banking: A Guide to Setting up and Running Biodiversity Credit Trading Systems*. New York: Taylor & Francis, 2008. Print.
- CH2M Hill. *Urban Stormwater Pollutant Assessment*. Report prepared for the North Carolina Department of Environment and Natural Resources, Division of Water Quality, 2000 Web. 24 April 2014.
- Chesser, John. *Charlotte and Raleigh Top U.N. List of Fastest Growing Large U.S. Cities*. UNC Charlotte Urban Institute, 2014. Web. 8 February 2015.
- City of Charlotte Umbrella Stream and Wetland Mitigation Bank*. Charlotte-Mecklenburg Storm Water Services, 2015. Web. 21 April. 2015.
- Clinton, Barton D. "Stream Water Responses to Timber Harvest: Riparian Buffer Width Effectiveness." *Forest Ecology and Management* 261:6 (2011): 979-988. Web. 16 March 2015.
- Compensatory Mitigation*. Environmental Protection Agency, 2015. Web. 24 April 2014.
- County Estimates*. North Carolina Office of State Budget and Management, 2015. Web. 25

February 2015.

Dumas, Christopher F., Templeton, Scott R. “Estimating and Analyzing the Costs of Design-Bid-Projects for Stream Mitigation in North Carolina: Final Report.” Report prepared for North Carolina Ecosystem Enhancement Program, 2007. Web. 10 March 2015.

*Endangered and Threatened Species of North Carolina*. U.S. Fish & Wildlife Service, 2013. Web. 24 April 2014.

*Draft Total Maximum Daily Load for Mercury in the Waters of Jordan Creek, Idaho*. Environmental Protection Agency, 2014.

Farhan, Y., Zregat, D., & Farhan, I. “Spatial Estimation of Soil Erosion Risk Using RUSLE Approach, RS, and GIS Techniques: A Case Study of Kufranja Watershed, Northern Jordan.” *Journal of Water Resource and Protection* 5:12 (2013): 1247. Web. 9 January 2015.

Federal Water Pollution Control Act. Pub. L. 107-303. Nov. 2002. 33 U.S.C. §§1251-1387. Web. 9 January 2015.

Gardner, Royal C., Radwan, Theresa J.P. “What Happens when a Wetland Mitigation Bank Goes Bankrupt?” *Environmental Law Reporter* 9 (2005): 10590-10604. Web. 9 January 2015.

*Geospatial Data Gateway*. U.S. Department of Agriculture, Natural Resources Conservation Service, 2014. Web. 24 April 2014.

*Grants*. North Carolina Wildlife Habitat Foundation, 2015. Web. 9 January 2015.

Hallwood, Paul. “Contractual Difficulties in Environmental Management: The Case of Wetland Mitigation Banking.” *Ecological Economics* 63 (2007): 446-451. Web. 24 April 2014.

Kusler, Jon A. *Protecting and Restoring Wetlands: A Guide for Land Trusts*. Association of State Wetland Managers, 2009. Web. 9 January 2015.

*Market Feature & Rules*. Ecosystem Marketplace, US Wetland Banking, 2014. Web. 21 April 2014.

*Mitigation Banking Factsheet*. Environmental Protection Agency, 2014. Web. 24 April 2014.

Mogensen Mitigation, Inc. *Tar River Headwaters Stream Mitigation Bank Final Prospectus*. U.S. Army Corps of Engineers, Wilmington District, 2012. Web. 20 November 2014.

Mogensen, Richard K. *Agreement to Establish an Umbrella Mitigation Banking Instrument in*

- the Tar-Pamlico River Basin for Riparian Buffer and Nutrient Offset Mitigation Credits Pursuant to the Pamlico Nutrient Strategy*. NC Ecosystem Enhancement Program, 2013. Web. 6 February 2015.
- National Land Cover Database*. Multi-Resolution Land Characteristics Consortium, 2014. Web. 7 September 2014.
- N.C. Gen. Stat. § 15A NCAC 02B .0240 (2010).
- N.C. Gen. Stat. § 15A NCAC 02B .0258 (2001).
- N.C. Gen. Stat. § 15A NCAC 02B .0259 (2000).
- Riparian Forest Buffer*. Natural Resources Conservation Service, 2003.
- Partners for Fish and Wildlife Program*. United States Fish and Wildlife Service, 2012. Web. 9 January 2015.
- PLOAD version 3.0: An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects*. U.S. Environmental Protection Agency, 2001. Web. 7 September 2014.
- Riparian Buffers*. North Carolina Division of Water Resources, 401 & Buffer Permitting Unit, 2015. Web. 21 April 2015.
- Robertson, Morgan M. “Emerging Ecosystem Service Markets: Trends in a Decade of Entrepreneurial Trends in a Decade of Entrepreneurial Wetland Banking.” *Frontiers in Ecology and the Environment* 4 (2006): 297-302. Web. 23 April 2014.
- Robertson, Morgan. “The Work of Wetland Credit Markets: Two Cases in Entrepreneurial Wetland Banking.” *Wetlands Ecology and Management* 17:1 (2009): 35-51. Web. 9 January 2015.
- Scodari, Paul, Martin, Steve, Willis, Aaron. *Implementing Financial Assurance for Mitigation Project Success*. U.S. Army Corps of Engineers, Institute for Water Resources, 2011. Web. 9 January 2015.
- Slee, Kendall. *Land Trusts Test the Waters of Wetlands Mitigation*. Land Trust Alliance, 2000. Web. 9 January 2015.
- Stream Mitigation Guidelines*. United States Army Corps of Engineers, Wilmington District, 2003. Web. 11 August 2014.
- Suriyaprasit, M., & Shrestha, D. P. “Deriving Land Use and Canopy Cover Factor from Remote Sensing and Field Data in Inaccessible Mountainous Terrain for Use in Soil Erosion

- Modelling.” *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 37:PartB7 (2008): 1747-1750. Web. 9 January 2015.
- Tar River Land Conservancy*. Tar River Land Conservancy, 2014. Web. 7 September 2014.
- Tar-Pamlico Nutrient Strategy: Introduction*. North Carolina Department of Natural Resources, Division of Water Quality, 2015. Web. 8 February 2015.
- Terando, Adam J., Costanza, Jennifer, Belyea, Curtis, Dunn, Robert R., McKerrow, Alexa, Collazo, Jaimi A. “The Southern Megalopolis: Using the Past to Predict the Future of Urban Sprawl in the Southeast U.S.” *PLOS One* 9:7 (2014): 1-8. Web. 11 April 2015.
- Teresa, Sherry. “Perpetual Stewardship Considerations for Compensatory Mitigation and Mitigation Banks.” *Stetson Law Review* 38 (2008): 337-356. Web. 9 January 2015
- Teresa, Sherry. *The Demise of The Environmental Trust*. Ecosystem Marketplace, 2006. Web. 24 April 2014.
- Turner, R. Eugene, Redmond, Ann M., Zedler, Joy B. “Count it by Acre or Function— Mitigation Adds Up to Net Loss of Wetlands.” *Environmental Law Institute* 23:6 (2001): 5-16. Web. 9 January 2015.
- U.S. Environmental Protection Agency (2014, September). Draft Total Maximum Daily Load for Mercury in the Waters of Jordan Creek, Idaho.
- W.K. Dickson & Co., Inc. *Fishing Creek Local Watershed Plan*. Report prepared for the North Carolina Department of Environmental and Natural Resources, Ecosystem Enhancement Program, 2012 Web. 24 April 2014.
- Watershed Planning*. N.C. Ecosystem Enhancement Program, 2015. Web. 9 January 2015.
- Wetland and Stream Mitigation: A Handbook for Land Trusts*. Land Trust Alliance, 2012. Web. 24 April 2014.
- Yongsik Kim. “Soil Erosion Assessment using GIS and Revised Universal Soil Loss Equation (RUSLE).” (2014). Web 9 January 2015.
- Zhang, W., Zhang, Z., Liu, F., Qiao, Z., & Hu, S. “Estimation of the USLE Cover and Management Factor C using Satellite Remote Sensing: A Review.” In *Geoinformatics, 2011 19th International Conference on* (pp. 1-5). IEEE. (2011). Web. 9 January 2015.

## Appendix.

### A1. Sub-watershed Re-categorization.

<b>HUC12 Basin</b>	<b>Sub-Watershed</b>	<b>Stream Basin</b>
030201010101	1	Cub Creek
030201010102	2	Headwaters Tar River
030201010103	3	Shelton Creek
030201010104	4	North Fork Tar River
030201010105	5	Rocky Creek-Tar River
030201010106	6	Aycock Creek-Tar River
030201010201	7	Fishing Creek
030201010202	8	Ruin Creek
030201010203	9	Tabbs Creek
030201010204	10	Middle Creek-Tar River
030201010301	11	Kings Creek-Tar River
030201010302	12	Lynch Creek
030201010303	13	Bear Swamp Creek-Tar River
030201010304	14	Jumping Run-Tar River
030201010401	15	Upper Cedar Creek
030201010402	16	Lower Cedar Creek
030201010403	17	Norris Creek
030201010404	18	Crooked Creek
030201010405	19	Town of Bunn-Tar River
030201010501	20	Peachtree Creek-Boddies Millpond
030201010601	21	Lake Sagamore-Cyprus Creek
030201010602	22	Turkey Creek
030201010701	23	Headwaters Sandy Creek
030201010702	24	Devils Cradle Creek
030201010703	25	Upper Sandy Creek
030201010704	26	Red Bud Creek
030201010705	27	Middle Sandy Creek

A2. RUSLE Annual Sedimentation Loading Rate.

<b>Sub-watershed Number</b>	<b>Tons/Acre/Year</b>
26	3600
17	4851
24	7088
3	8165
1	10167
18	12569
14	13942
5	14149
23	17127
10	24249

A3. Stream sites project costs and return.

<b>Stream</b>	<b>Sub-watershed</b>	<b>Stream Order</b>	<b>Length</b>	<b>Stream Score</b>	<b>Cost</b>	<b>Price</b>	<b>Return</b>
1	10	1	864.28	1.5	73,464- 216,070	331,884	115,813- 258,420
2	14	1	1354.37	4.3	115,122- 338,593	520,078	181,486- 404,957
3 Shelton Creek	3	3	2661.58	5.5	226,234- 665,395	1,022,047	356,652- 795,812
4 Fox Creek	3	3	2638.16	3.4	224,244- 659,540	1,013,053	353,513- 788,810
5 Fox Creek	3	3	3920.61	6.4	333,252- 980,153	1,505,514	525,362- 1,172,262